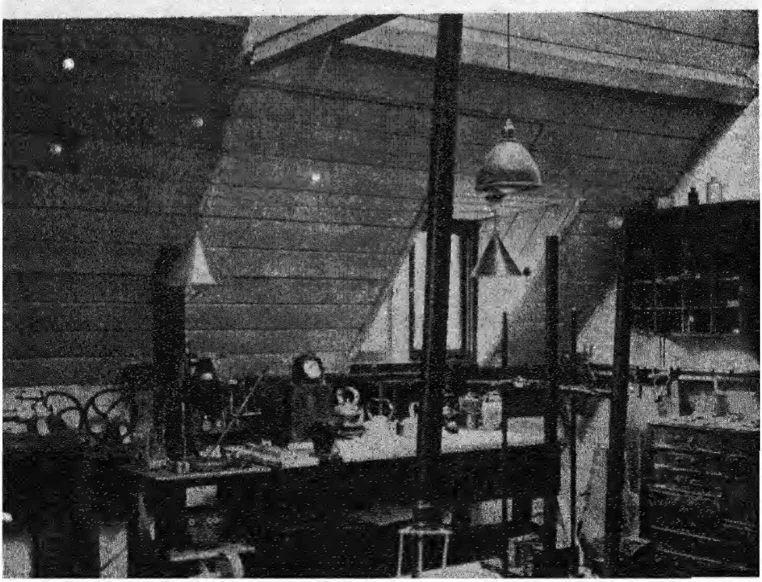
THE

LABORATORY

WORKSHOP

Plate I

A laboratory workshop



An attic room converted into a laboratory workshop

THE LABORATORY WORKSHOP

A SIMPLE COURSE IN APPARATUS MAKING AND THE USE OF TOOLS

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PREFACE

THE writers of this book were responsible for the workshop practice which formed a distinctive part of the Science Courses held at Cheltenham by the Board of Education in 1930 and 1931. It became apparent that many teachers would welcome a book dealing with the functions of a laboratory workshop and, at the suggestion of the organiser, Mr. E. G. Savage, H.M.I., this work has been undertaken in order to reach a wider circle than is possible at a fortnight's Course.

We wish particularly to stress the fact that the fundamental processes needed, even in a complex piece of apparatus, are few in number and quite simple. We venture to make this point since it is in danger of being overlooked by many men and perhaps even more by women teachers who often regard a workshop as something outside their sphere. Our hope is that the book may encourage the design and construction of home-made apparatus, not only because of the pleasures and advantages which the use of a laboratory workshop brings, but also because in these times when economy is urged and the allocation of money for scientific apparatus is all too small, self-help of this kind seems the only way in which efficient teaching is to be secured.

The apparatus described in Chaps. XI and XII have been selected to show something of the wide range of equipment that it is possible to construct, at very small cost, by the application of the simple processes described in the earlier chapters. Users of the book should have little difficulty in applying these processes to their own requirements.

The line drawings and photographs for the illustrations have been prepared by the writers.

Our very special thanks are due to Miss M. A. Reid, B.Sc., who undertook the reading of the manuscript, correction of the proofs and the compilation of the index, and whose encouragement and sympathetic interest has been our never-failing support.

Our thanks are due to the following firms for the drawings of certain tools in Chapters I and II:

British Tool and Engineering Co., Ltd. (Bench drilling machine, Item 18).

Greenfield Tap and Die Corporation (Little Giant screw cutting appliances, Items 1–7).
C. and J. Hampton, Ltd. (Record vices, Figs. 2 and 3, and Stanley pattern planes, Items 76 and 77).
Schollhorn and Co. (Bernard pliers, Items 49 and 50).

Other acknowledgements are made under the respective figures.

E. H. DUCKWORTH
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INTRODUCTION

A SCIENCE laboratory forms part of the recognised equipment of every up-to-date school and many schools have spent large sums on elaborate buildings and ready-made apparatus, yet it is quite rare to find any of these laboratories with a suitably equipped workshop for the repair and construction of apparatus.

The type of laboratory that has been equipped in every detail from a catalogue is far too common and rather depressing in its lack of originality and flexibility.

Most science masters have had the experience of delving into cupboards and finding a dusty collection of broken balances, galvanometers and such-like that are no longer in use owing to the lack of some small screw or essential part. The old apparatus can be packed up and sent back to the makers for repairs, but this involves trouble, time and money.

A small workshop enables repairs to be done at negligible expense without delay and, what is even more important, the teacher of science with a knowledge of the use of tools is able to try experiments that are not found in school text-books and to introduce into his teaching a freshness and originality that is often sadly lacking in these days of certificate examinations.

The modern science student at a University receives little training in manual dexterity. The lecture experiments are set up by skilled assistants and the laboratory work seldom calls for much manipulative skill, with the result that few science masters or mistresses have an opportunity of learning the use of tools and the construction and adjustment of apparatus.

The late Sir James Dewar often deplored this lack of ability in students under his notice. His own dexterity, displayed in his work and lectures was founded in boyhood days when he tried his hand at making fiddles. He regarded this early training as the most important part of his education.

During recent years the Board of Education in England has attempted to remedy this deficiency in the school and university training of science teachers by the organisation of vacation courses in laboratory arts. The present writers have had opportunities of giving instruction at some of these courses and noting

the special difficulties and requirements of science masters and mistresses.

It is hoped that this book will assist science teachers to make a workshop a useful and vitalising part of their equipment.

In general education a laboratory workshop can play an important part. Most school workshops come under one or other of three categories. A wood workshop, a metal workshop or an engineering workshop.

A wood workshop requires no description, a metal workshop is usually devoted to the making of ornamental articles in sheet metal and simple forging, and an engineering workshop implies an equipment of lathes, milling machines and so forth.

Many public schools, with engineering workshops fitted with machine tools, find a difficulty in providing suitable work of a not too expensive character for the students to practise on.

Both wood and metal workshops are of value provided they do not degenerate into places for wearisome exercise in the making of joints or the shaping of material to set forms, such exercise pieces to finish up ultimately on a scrap heap.

The wide development of science in schools has given the opportunity for a new type of workshop, where science and handcraft are happily linked together, and where students can learn that general handiness with tools for accurate working in both wood and metal, which is of value, not only to the future science worker, but to any man or woman living in the present age of mechanism. Few boys after leaving school, unless they take up engineering as a profession, are likely to have the use of workshops equipped with lathes and machine-tools; on the other hand a little workshop provided with wood-working tools and mechanic's hand tools for metal work is readily acquired and provides the owner with a life-long, pleasurable and most useful hobby, in that it enables him to make and repair many things required or used in home or garage.

In a laboratory workshop both staff and students have an opportunity of making up all sorts of interesting models and experimental apparatus, of trying out old, almost forgotten, experiments or attempting new ones. An escape is provided from the stagnation of examination science and something of the spirit of a research laboratory is introduced into school studies.

An elaborate, expensive, equipment is not necessary, but it does include, not only the usual carpenter's tools, but such things as files, soldering irons and stocks and dies for cutting screw-threads, also a supply of suitable materials.

The omission of a lathe, so far as beginners are concerned, is rather an advantage than otherwise, since the art of inventing, improvising and adapting tends to be stimulated by its absence. A workshop allied to the laboratory helps students to learn the application of knowledge gained from books or in the lecture room.

A student who has constructed a telephone or microscope projector, or wrestled with the difficulty of making and adjusting apparatus to show the interference colours of soap films on a screen has more real knowledge about these things than one who has only read text-book descriptions or looked at demonstration apparatus.

Many schools suffer from lack of science equipment yet, as the following pages set out to show, it is possible to make a great range of laboratory equipment at very small cost.

All the apparatus described has been constructed and tested out by students in England or Nigeria, and some of it has been exhibited in London at meetings of the Science Masters' Association.

The writers hope that the book may serve as a practical guide to the equipment of a laboratory workshop, provide help to teachers and students in the use of tools, and give information regarding the construction of a wide range of apparatus, also hints on the setting up of interesting experiments that are seldom included in text books and are of value in connection with school science exhibitions.

Many of these experiments, especially if demonstrated with home-constructed apparatus, help to stimulate interest in science and show something of its romance.

CHAPTER I

THE SELECTION AND GENERAL EQUIPMENT OF A LABORATORY WORKSHOP

THE selection of a room, or space in the laboratory to be used as a workshop is subject to various considerations. The workshop should, if possible, be close to the laboratory. If a separate room cannot be used, a place can often be found in the laboratory itself, for preference in the physical laboratory. The fumes of a chemical laboratory can cause steel tools to rust over-night. An elaborate building is not necessary; thought should be given to the creation of a workshop atmosphere; white paint and glazed tiles are incompatible with the surroundings of a workshop. At the same time arrangements should be made to keep everything neat and tidy, since an array of well kept tools and materials, all ready to hand and not hidden away in store boxes, has a valuable psychological effect in stimulating ideas. If the workshop is to be used by the science staff, a laboratory assistant and a few students only, quite a small room will suffice. In cold countries provision should be made for heating during the winter time; it is difficult to do accurate work with metal if the hands are numb. In warm countries the workshop should be as airy as possible.

Many schools already have carpenters' workshops and it is often an advantage to do most of the woodwork required in this shop, reserving the laboratory workshop for metal work. This avoids the dust and litter of sawdust and shavings. Small tools, little nuts and so on tend to get lost in a mass of shavings. If a separate room or space cannot be detailed for woodwork, then the next best thing is to have a separate bench, and if this is not possible it is always a good rule after using a plane to sweep up the shavings before going on to other work (Plate IIA, page 183).

A good firm bench is essential. A design for a bench is shown (Fig. 1). This may be made of pitch pine, deal or wood of similar type. Deal is quite suitable and cheaper than pitch pine. The top of the bench should be made of thick wood and be massive enough to stand the blow of a mallet or hammer without rebound.

A bench, to be used for woodwork, is conveniently made lower

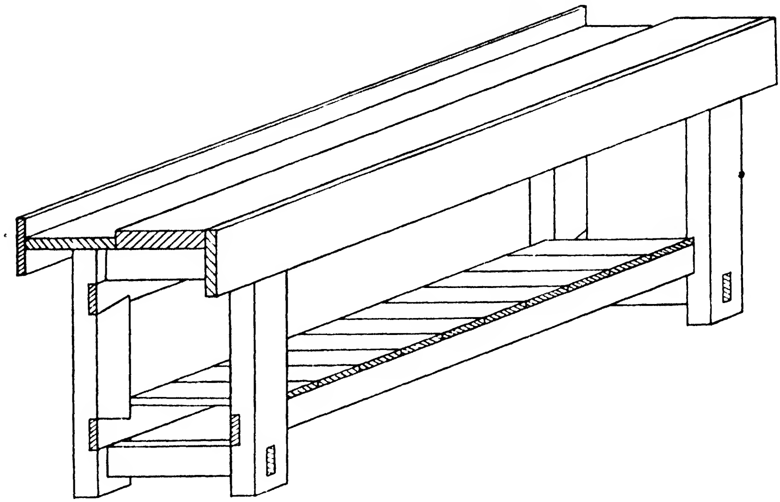


Fig 1 A workshop bench

than one for metal work. When using a plane or chisel the worker requires to stand well over his work. Laboratory metal work involves much delicate marking out and drilling, a bench that is too low necessitates uncomfortable stooping. For wood work a bench height of 2′ 6″ is recommended and for metal work 3′ is not too high. A bench for combined wood and metal work is conveniently made 2′ 10″ high. It is often possible to convert an ordinary laboratory bench. To protect the polished top from the marks and cuts inevitable in a workshop the teak or other top of good wood can be protected by covering it with some planed lengths of cheap wood firmly fastened down with screws. A laboratory bench free from under-cupboards is to be preferred since it gives a better standing or sitting position. Drawers on the other hand are an advantage. The bench must be provided with a parallel-jaw vice. The number of vices fitted will depend on the number of workers likely to use the shop at any one time. A vice to every worker is ideal, but much can be done with one vice to every two or even three workers; a vice is in such constant use that one vice per worker should be aimed at if possible.

A vice with jaws 4″ wide of the type shown (Fig. 2), is a useful size. This may look large and clumsy, but will be found in practice to be capable of holding small delicate work and it is a great convenience to have at least one good strong vice when iron-strip has to be hammered over and bent without heating or ½″ diam. iron rods have to be provided with a screw-thread.

Small vices with jaws 2″ wide are quite cheap and will serve for the majority of purposes, but if possible instal both a large and a small vice. Vices are made in cast iron and steel. Steel vices are much stronger and more expensive than cast iron ones. Since a vice should never be hit with a hammer, cast iron ones are quite satisfactory if this action be avoided.

The jaws of a good vice should go together fair and square and be free from side wobble. Much of the wood-making to be done in connection with a laboratory workshop can be carried out with

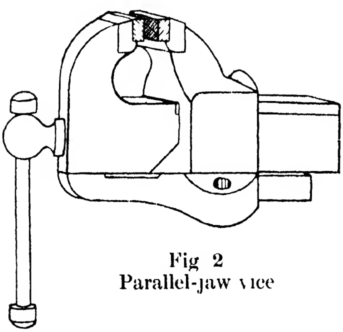


Fig 2
Parallel-jaw vice

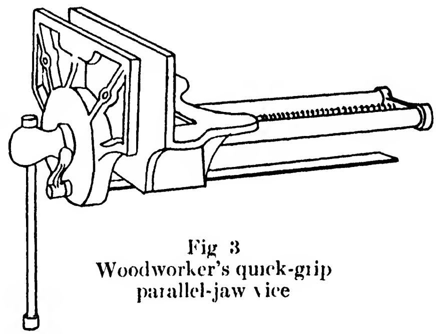


Fig 3
Woodworker's quick-grip parallel-jaw vice

the help of an ordinary parallel-jaw vice, but if space allows it is useful to instal an ordinary carpenter's vice. A metal vice of the quick-grip type shown (Fig. 3), is easily attached to a bench and is a great help.

When attaching a parallel-jaw metal vice to a bench, select a firm place near to a bench leg or support. The marking out of the positions of the holding down bolts or screws requires care. Clamp a long straight metal bar in a vertical position in the jaws and so place the vice on the bench that the bar is just clear of the edge of the bench (Fig. 4). Avoid as far as possible the vice projecting out over the bench top, at the same time it must project far enough to enable it to hold long vertical rods that extend below the level of the bench top. The jaw edges, as seen from above, must be parallel to the bench top. Test with a long rod clamped in the jaws in a horizontal position (Fig. 5). A mechanic usually contrives to fix his vice at such a height that he is able to rest his elbow on the top of it when standing by the side of the bench (Fig. 6).

This arrangement is seldom possible in a laboratory workshop where the vice is likely to be used by people of different height.

Small vices can be secured to the bench top with strong countersunk head wood screws, but a better arrangement, essential in

the case of large vices, is to fasten them down with nuts and bolts. Note the diameter of the holes in the base of the vice, one is usually uncovered only when the jaws are partly opened. Obtain some iron or bright-steel Whitworth bolts of a size to just pass through these holes and of a length about ½″ longer than the combined thickness of bench top and vice base.

Suppose a ⅜″ diam. bolt has been found to be suitable. Mark the position of the vice bolt holes as described above and with the help of a ⅜″ diam. bit held in a carpenter's brace, bore holes in the bench at those places.

Put the vice in position; if the bolts are a little difficult to get through the wood, although holes of the correct diameter have been bored, just tap them through with a hammer. Sometimes in fitting a vice to a laboratory bench it will be found that the under support of the bench top or a drawer (Fig. 7), will prevent the vice being fixed in such a way as to project far enough. In this case it may be necessary to cut some of the wood away from the inside with the help of a wood chisel or gouge to give room for a nut and washer (Fig. 8). If everything is in order, put washers on the bolts and tighten up the nuts with a spanner. If a bolt tends to turn round as a spanner is used on the nut, then use two spanners, one to hold the bolt and the other to turn the nut.

Sometimes it will be found that the screw-thread on the bolt does not extend far enough to enable the nut to be tightened up. In this case remove the bolt and cut more thread on it with the help of a die (see screw cutting, Chapter V). Failing the use of a die find a nut with an inside diameter large enough to pass over the bolt thread and use it as a packing piece with washers on either side (Fig. 9).

Bench and vice having been provided for, the next consideration is the arrangement of tools. It is wise to study economy of movement and have all commonly used tools as near to hand as possible. Much time can be saved in selecting the correct tools and in tidying up, if unnecessary walking about the workshop can be avoided.

It is much better to keep all tools out and ready for immediate use than to store them in boxes and drawers. If displayed in definite positions the loss of tools is readily detected and they are easily examined for rust.

The skilled craftsman knows instinctively what tools to use for any particular piece of work and may almost be compared with a musical composer selecting the right note. It is surprising the number of tools that may be called into use for the completion

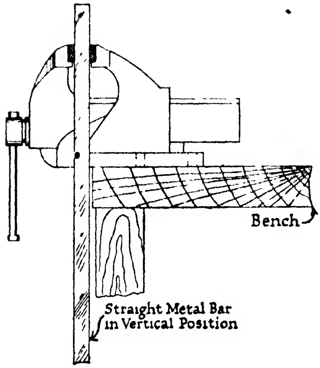


Fig. 4.

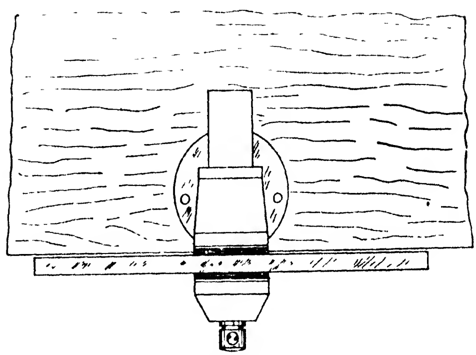


Fig. 5.

Method of determining the correct position of bolt holes when attaching a vice to a bench

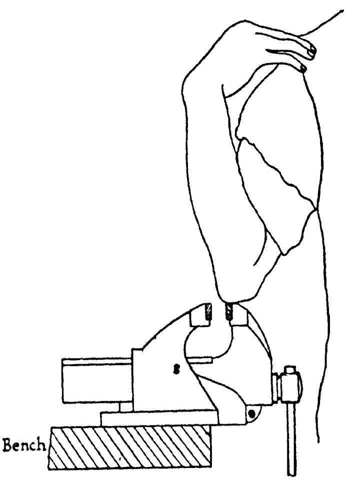


Fig. 6.
Method of testing a vice for height

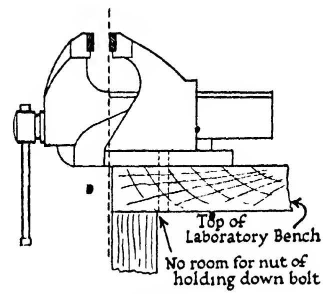


Fig. 7.

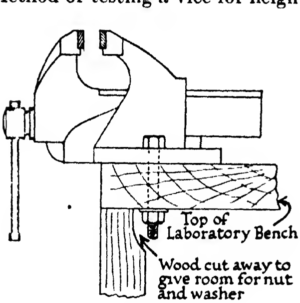


Fig. 8.

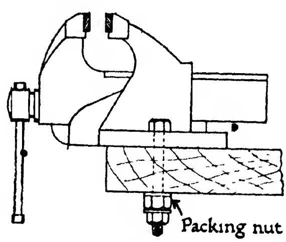


Fig. 9.
Method of using holding-down bolts that are not threaded far enough down the stem

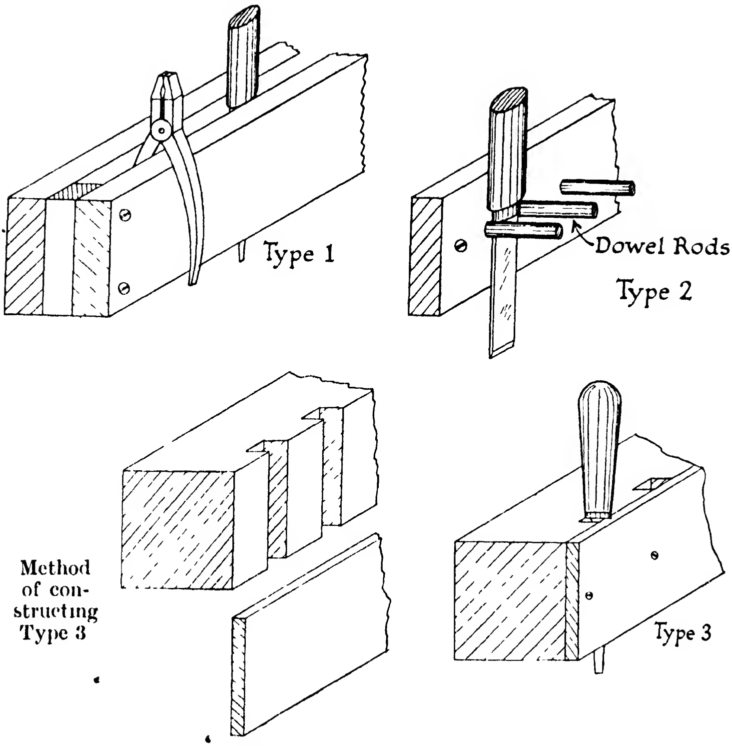


Fig. 10. Wooden tool racks

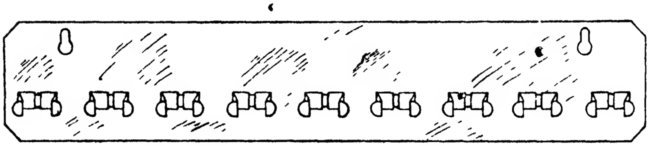


Fig. 11. A metal clip form of tool rack

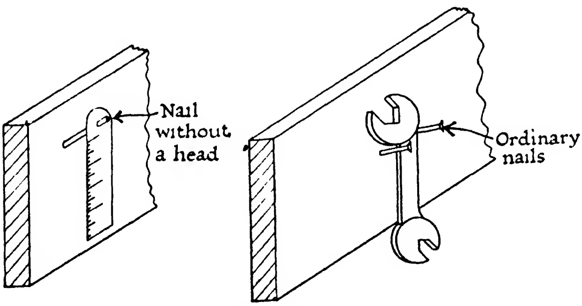


Fig. 13. Tool holders

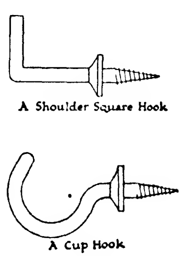


Fig. 12.
Tool holders

of quite simple apparatus, hence the necessity for tools arranged ready to hand.

Tools like files, hammers and chisels can be held in loops of leather strap, wooden racks or metal clips.

Leather straps can be purchased quite cheaply at a harness maker's in long lengths without metal buckles and are easily made up into loops of different sizes to suit the tools; they can be attached to woodwork with round-headed brass or iron screws. Holes for the screws to pass through the leather can be made with a bradawl.

Wooden racks are cheaper to provide than leather loops and in some respects are more satisfactory (Fig. 10).

Tool dealers sell metal clips for holding tools, a few of these are often handy (Fig. 11).

Large tools like saws and a carpenter's brace are readily suspended on shoulder square hooks, cup hooks or nails (Fig. 12). Steel rules can hang from nails that have had their heads cut off (Fig. 13).

As far as possible arrange to keep the bench top clear of tools, except of course when work is in progress.

If the wall facing the bench be made of brick or concrete some difficulty will be experienced in attaching tool holders. In this case it is best to cover the wall to a height of a few feet with wooden boards. The wall will have to be plugged, the method of doing this is described in Sec. **201.** It is wise to keep the floor space as clear as possible to simplify sweeping up. A shelf under the bench is handy for storing boxes of oddments and a shelf about 6″ wide, opposite the bench and about 2′ above it provides a useful place for planes, small tools and tools of odd shape that do not readily slip into loops or other holders.

Cupboards are useful to store paint tins and brushes that tend to become unsightly, also to keep from the dust objects that have just been enamelled. Cupboards, also drawers, require periodic overhaul to prevent them becoming the abode of litter. Provide plenty of shelves for the storage of screws, nails and such like.

The bench used for woodwork should be fitted with a bench stop to enable wood to be planed. Ready-made, metal bench stops can be obtained. When these are used beginners are very liable to chip bits out of plane irons by continuing to plane when the edge of the stop has come flush with the wood being worked on (Fig. 14).

An alternative method is to bore a row of vertical holes in the bench top and fit these with dowel rods (Fig. 15). The rods should

be left about 1′ long. With the help of a mallet they can be knocked up from below to any required height. They readily prevent work slipping, do not get in the way, and no possible injury can be done to either the job or the plane.

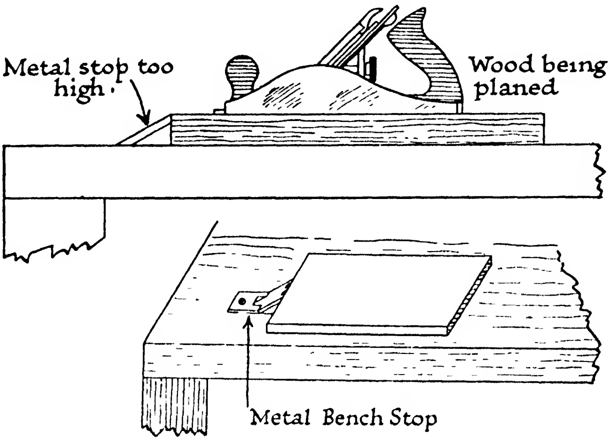


Fig. 14.

Racks should be made to carry a supply of strip, rod and sheet metal. Two types are shown (Fig. 16). Odds and ends of waste metal should not be thrown away, but kept in a special box. One box for brass and copper, another for iron and steel. Great economy can often be effected by using up odd bits instead of cutting into new supplies.

Screws are best bought in gross packets and are always rather difficult to keep tidy and sorted. The advantage of leaving the screws in their original packets is that the lengths and size numbers are printed on the packets.

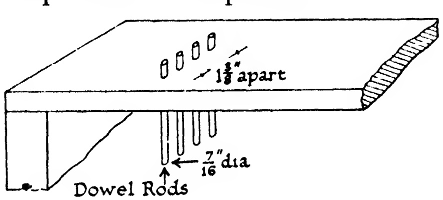
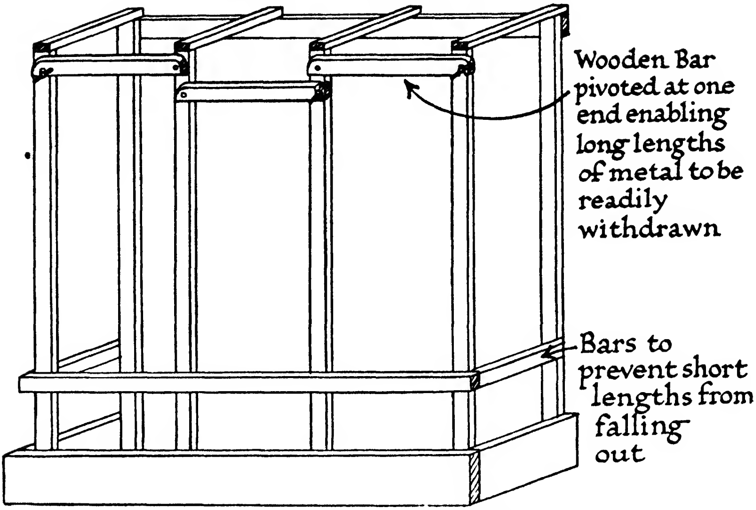


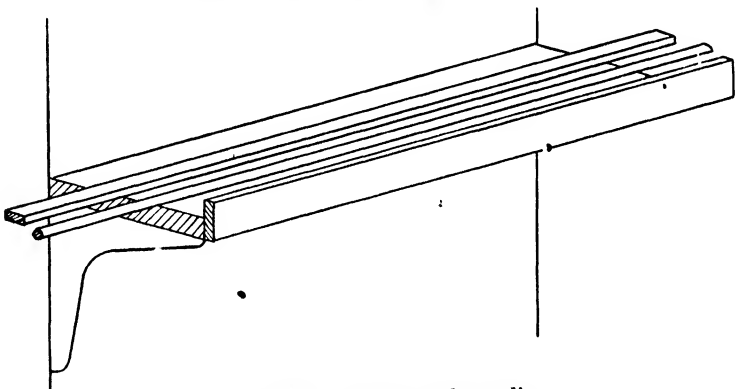
Fig. 15. A fool-proof and very efficient form of bench stop

It is often necessary to return unused screws to packets. It is troublesome to compare a screw held in the hand with the particulars on a label. For this reason it will be found advantageous to store the screws in labelled glass jars. Sorting is simplified, the stock remaining in reserve can be noted and iron screws are preserved from rust.

Old jam and honey pots with screw tops are excellent for the purpose and are cheap to replace if broken.



A rack of the umbrella stand type for holding metal supplies
The rack can be placed against a wall



A rack for holding metal supplies

Fig. 16.

The chief disadvantage of a pot is that it has to be tilted up to get out the contents, for this reason rectangular shaped tins are sometimes preferable.

Craven A cigarette tins form excellent screw containers. They are a gay red, free from unsightly lettering on the sides. The name is enamelled and not pressed out on the lid. Also the latter, being domed, gives good store space for the odd screw that is often so difficult to return to a packet that is nearly full and slightly disarranged.

The top of the tin should be painted over with black cycle enamel and the nature of the contents neatly printed in block lettering, using a fine brush and white enamel.

Old glass vaseline pots with enamelled screw tops make good containers for tiny nuts, washers and other small supplies.

If the shelf used for storing screw bottles be subject to vibration from the work bench it is wise to fit it with a raised strip of wood to prevent the bottles gradually slipping off.

When screws and small nuts have been used it is often found that some have been left out after the main tidying up has been effected. Time is saved if these are not returned to the correct pot or tin at once, but placed in a special open tin of mixed screws and nuts that is sorted out every month or so. One tin can be kept for wood screws and another for metal screws.

Some workers are very wasteful of emery and glass paper. When this has been used it should not be thrown away unless dirty or quite worn out. A special box or drawer should be kept for it.

A workshop requires good illumination.

If electric light be used, provide lamps for general illumination

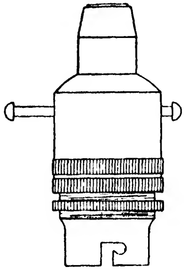


Fig. 17. An electric lamp holder with push-bar type of switch

and for a concentrated light on the work bench and vice. Metal shades, white enamelled on the inside, and of a shape to cut out all direct light are recommended for the latter purpose. They are somewhat expensive; a cheap, but less durable substitute is provided by cardboard ones.

Bench lights should be fitted with holder switches. Holder switches of the push bar type (Fig. 17) are much to be preferred to holder switches of the turn type. The former can be worked with one hand and the flexible connection is not bent when the switch is operated.

It is best to provide a separate soldering table or at any rate reserve a special place on the bench for soldering. This table or

bench place should be well removed from shavings. If a blow-lamp be used for heating soldering irons the latter precaution is most important to avoid danger from fire. Blow-lamps, unless carefully started up, are liable to squirt out a flaming jet of liquid paraffin (kerosene) and should always, on first pumping, be directed away from inflammable material. A soldering table covered with a piece of Uralite, a commonly used building material made of cement and asbestos, is particularly useful. A hot soldering iron can be placed on the table without fear of burning anything, little pellets of solder can be dropped on it and are readily picked up for use. If a whole table be not used for soldering a Uralite roofing

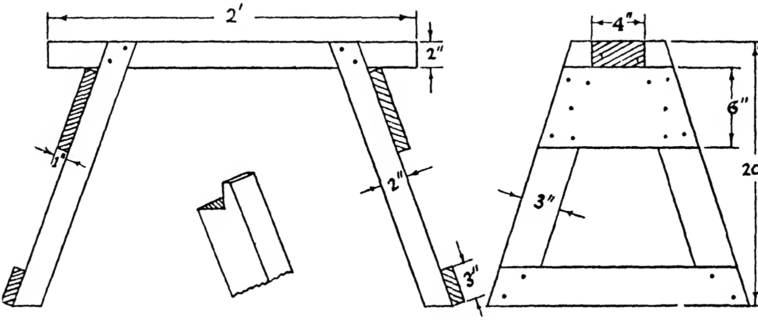


Fig. 18 A wooden sawing stool

tile measuring about 12″ square forms a suitable cover to part of the main bench.

An ordinary laboratory-stool should be available, sometimes a very steady hand is required and it is an advantage to sit down at the bench.

If the sawing of wood be not done in a carpenter's shop, or if the wood-shop is not near at hand or always available the wood can be supported on two laboratory stools or even chairs, but as these are very likely to get cut into by careless or over vigorous workers it is best to make two sawing-stools of the type shown (Fig. 18).

A supply of tincture of iodine, bandages and a pair of fine tweezers should be kept in a first-aid cabinet. Slight cuts are fairly common in a workshop and should not be neglected. Brass filings and chips however small should always be extracted and for this the tweezers are useful. Brass is much more liable to cause festering than either iron or steel.

A scrap-box for odds and ends can play a most important part in a laboratory workshop and provision should be made for such a store. As subsequent chapters show many apparently useless

oddments can be put to good use and often save much time and trouble in making up special parts.

The floor may be of wood planks, wood blocks, cement or even hardened mud, but in any case should be capable of being swept clean. The dust from woodworking is sometimes troublesome, this is largely obviated by treating the floor with a dust allayer such as Florigene. A cement floor should be sprinkled with a watering can before sweeping operations start. The last but by no means the least important part of the general equipment of a laboratory workshop is the provision of adequate facilities for cleaning up.

Old rags or cotton waste are handy for mopping up oil and paint. If these are not available it may be found that expensive glass cloths and dusters will be taken for the purpose.

One or two soft floor brushes are required and every bench should have a hand brush. Each brush should have a hole drilled through its handle, so that a loop of strong cord can be inserted. The brush can then be hung up and stored with the bristles off the ground.

It is not easy to sweep up filings without the help of a dust-pan. A piece of sheet tin plate may be bent up to form its equivalent. Two flat pieces of wood are handy for gathering up shavings and putting them in a waste box.

It may appear unnecessary to mention brushes and such domestic items yet the cleaning up process plays an important part in a workshop.

After working for some hours the bench will get littered with tools and it becomes difficult to find just the one required. When this happens it is always wise to stop work for a few minutes and tidy up, returning tools to their proper positions in holders and on shelves.

If small nuts and other parts are dropped on the floor they can usually be recovered by sweeping up. In any case it is always wise, as a measure of economy, to look over the last sweepings for odd screws, nuts and bolts and return them to their respective bottles or tins.

If gaps exist in the floor boards they should be filled in with slips of wood or valuable parts may be lost.

A rule should be made for one's own use and for the instruction of others that the workshop be left clean, tidy and in perfect order after each day's work.

A clean tidy workshop, no less than a laboratory, promotes clear thinking and accurate work.

Dr. Gladstone in his delightful sketch of Michael Faraday[1] under the heading, 'His Method of Working,' writes :

"He would put away each tool in its own place as soon as done with, or at any rate when the day's work was over, and he would not unnecessarily take a thing away from its place: thus, if he wanted a perforated cork, he would go to the drawer which contained the corks and cork-borers, make there what he wanted, replace the bores, and shut the drawer. No bottle was allowed to remain without its stopper; no open glass might stand for a night without a paper cover; no rubbish was to be left on the floor; bad smells were to be avoided if possible; and machinery in motion was not permitted to grate.

"In working, also he was very careful not to employ more force than was wanted to produce the effect. When his experiments were finished and put away, he would leave the laboratory and think further about them upstairs.

"This orderliness and this economy of means he not only practised himself, but he expected them also to be followed by any who worked with him; and it is from conversation with those that I have been enabled to give this sketch of his manner of working. This exactness was also apparent in the accounts he kept with the Royal Institution and Trinity House, in which he entered every little item of expenditure with the greatest minuteness of detail."

[1] *Michael Faraday*, by J. H. Gladstone, Ph.D., F.R.S., Macmillan & Co., 1873. Now out of print, but can sometimes be obtained second-hand.

CHAPTER II

TOOL EQUIPMENT

WHEN choosing tools it is always wise to select one with a maker's name or trade-mark stamped on it in preference to one not so marked. A tool that a maker is ashamed to put his name on is usually badly tempered or otherwise poor. A good quality tool will last a lifetime if properly used.

Beware of combination tools that are supposed to function as a hammer at one end, a screwdriver at the other and half a dozen other things in between. Such tools, with a few exceptions, are never used by workmen. In the case of young people selecting tools and starting to build up the nucleus of a little home-workshop it is wise to select a good mechanic's or carpenter's tool in preference to the cheap, but usually worthless 6d. store article. The best policy is to obtain tools from a dealer who does a good trade with men who have to live by the use of tools or from one of the large London firms engaged in dealing with engineering concerns; some of these are prepared to give substantial discount rates to schools, colleges and laboratory workers.

A study of the catalogue of one of the large London tool dealers can be most instructive, but at the same time rather bewildering. The number of different hammers, files, screwdrivers and so on that can be bought, makes selection by the inexperienced a little difficult. This chapter is to indicate just those tools that have been found most useful in a laboratory workshop.

The number of tools that might be bought and found useful is almost unlimited. If time is no object it is possible to make almost anything, even a bicycle, with little other equipment than a hacksaw and file, but few of us have the leisure of a prisoner of war or the patience of primitive peoples who, as all know, often produce wonderful results with the help of simple tools.

Now it is possible to use a tool in many different ways and for more than one purpose. A file can be used to file, but the tang end is sometimes handy for enlarging holes. On the other hand the tang end of a file, uncovered by a handle, when the tool is used for its normal purpose, can inflict an unpleasant cut and it is much better to spend a few pence and buy a proper tool for enlarging

holes. A multiplicity of screwdrivers is unnecessary, but at the same time a reasonable selection is required. A screwdriver strong enough for screwing together a packing case is scarcely suitable for carrying out the delicate adjustment of a moving coil galvanometer or tightening the tiny screws of a spectacle frame.

When a reasonable outfit of tools has been gathered together and possibly selected during a number of years with the care of a connoisseur, it is wise, before farther purchases are made, to ask oneself 'Will it enable me to increase the range, accuracy or efficiency of my work?'

Certain American firms are world famous for the precision and beauty of construction of mechanic's fine tools; during recent years one or two Sheffield firms have turned their attention to this line of manufacture and are now producing a good range of such tools at competitive prices.

Lists of tools are given. List 'A' is of tools that should find a place in every science laboratory that can be regarded as reasonably equipped. It is also the equipment that the private experimenter or the home mechanic who wishes to do domestic or garage repairs should start to accumulate.

A drilling machine and a big 4″ vice, in addition to a 2½″ one, are not absolutely essential. The drilling machine is the more important of the two and is invaluable, not only as a saver of time and labour, but as an aid to accuracy.

List 'B' is of additional tools that will be found very useful and can well be added as funds permit.

If the workshop is to be used by several workers a more liberal supply of certain tools will be necessary; some tools are in constant use while others are less frequently employed.

The third column in the lists indicates a satisfactory supply for twelve students.

Certain special tools, not included in these lists, but described and illustrated in other parts of the book can be purchased if and when the need for them arises.

The prices shown are only approximate, current prices can always be obtained from a tool dealer.

The cost of American tools to buyers in England is increased by duties and it is well to enquire if a satisfactory English made substitute has appeared on the market.

Ten, twenty or thirty pounds spent on tools and workshop materials may, at first sight, appear excessive, but as pointed out in the Board of Education publication *Science in Senior Schools*[1]

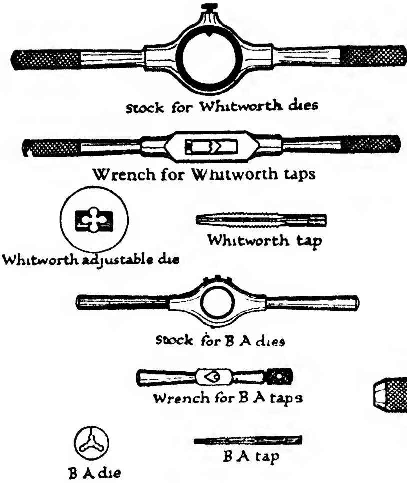
[1] H.M. Stationery Office, 1/6.

it is money wisely expended. Money in the case of new laboratories, is often wasted on over-elaborate furniture, benches and so on. Tools are more important than furniture. With wise control of expenditure on furniture all the tools needed can be bought and the total cost of the laboratory need not exceed what is now often paid.

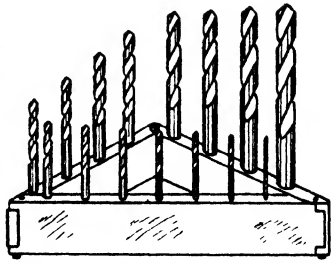
If tools are available, much money can be saved over the purchase of completed pieces of apparatus and in repairs. The knowledge of materials to be gained in a workshop is a valuable asset to science teaching, other advantages have been pointed out in the Introduction.

LIST 'A'

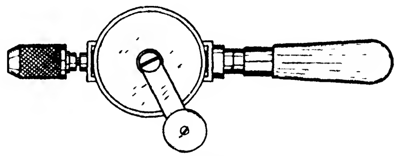
Item No.	No. reqd.	No. reqd. for 12 workers	DESCRIPTION	Approx. Price single tool or set £	s.	d.
1	1	2	Stocks and Adjustable Dies $\frac{1}{4}''$ $\frac{3}{8}''$ $\frac{1}{2}''$ Whitworth. One taper tap per size	1	14	0
2	1	2	Stocks and Adjustable Dies $\frac{1}{8}''$ $\frac{3}{16}''$ $\frac{1}{4}''$ Whitworth. One taper tap per size	1	0	0
3	1	2	Stocks and Adjustable Dies. Size 0 1 2 3 4 5 6 and 9. Brit. Ass. One taper tap per size	1	0	0
4	2	2	Whitworth right hand taper taps $\frac{1}{8}''$			6
5	2	2	" " " " " $\frac{3}{16}''$ ..			6
6	2	2	" " " " " $\frac{1}{4}''$			6
7	2	2	Drop-Forged Adjustable Wrenches, Jaws open $\frac{15}{16}''$		2	0
8	1	2	Set carbon steel, twist drills on metal stand, $\frac{1}{16}''$ to $\frac{1}{2}'' \times \frac{1}{64}''$		12	6
9	4	4	Twist Drills carbon steel $\frac{1}{64}''$			$2\frac{1}{2}$
10	4	4	" " " " $\frac{1}{32}''$			$2\frac{1}{2}$
11	4	4	" " " " $\frac{3}{64}''$			$2\frac{1}{2}$
12	4	4	" " " " $\frac{1}{16}''$			$2\frac{1}{2}$
13	4	4	" " " " $\frac{5}{64}''$			$2\frac{1}{2}$
14	4	4	" " " " $\frac{3}{32}''$			3
15	4	4	" " " " $\frac{1}{8}''$			3
16	4	4	" " " " $\frac{3}{16}''$			3
17	1	3	Hand Drill to take drills up to $\frac{1}{4}''$ 12/– to	1	5	0
18	1	2	Bench type drilling machine with chuck to take drills up to $\frac{1}{2}''$ .. .. .. £1 to	2	10	0
19	2 sets	2 sets	Spare springs for chuck of drilling machine ..			3
20	1	Ref. Ch. I, Fig. 2	'Record' Parallel Vice with 4″ jaws ..		16	6
21	1	"	" " " " $2\frac{1}{2}''$ "		7	9
22	1	3	Jeweller's small hand shears, straight blades		1	6
23	1	3	.. .. curved blades		2	0



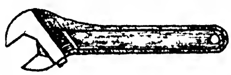
Nos 1–6 Screw cutting tools



No. 8 Carbon steel twist drills on metal stand

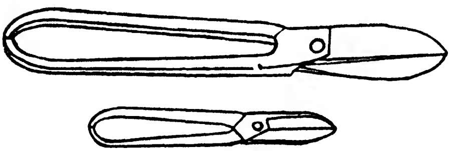


No. 17. Hand drill

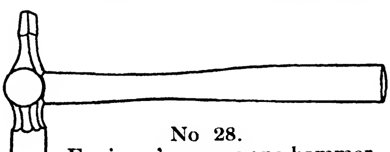


No. 7. Drop-forged adjustable wrench

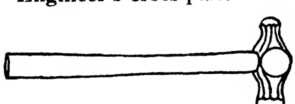
Nos. 22 and 23 Jeweller's snips, straight and curved blades



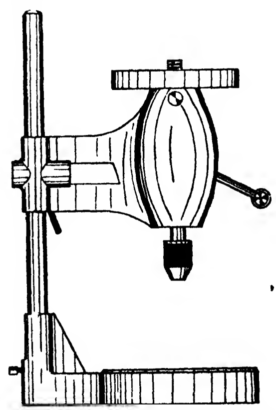
Nos. 24 and 25. Tinman's snips



No 28.
Engineer's cross pane hammer



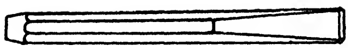
No. 29. Engineer's ball pane hammer



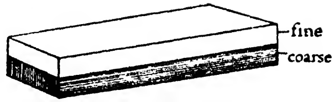
No. 18. Bench type drilling machine

Cw

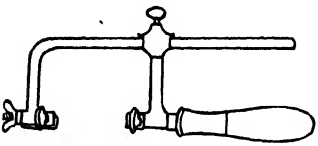
Item No.	No. reqd.	No. reqd. for 12 workers	DESCRIPTION	Approx. Price single tool or set £	s.	d.
24	1	3	Tinman's Snips, 12″ straight		3	0
25	1	2	,, ,, 6″ ,, ...		1	9
26	1	3	Ball Pane Hammer with handle, 3oz. ..			
27	1	3	,, ,, ,, ,, ,, 6oz. ..			
28	1	4	Engineer's Hammer Cross Pane with handle, $1\frac{1}{2}$lbs.		2	6
29	1	4	Engineer's Hammer Ball Pane with handle, 1lb.		1	4
30	1	3	Cold Chisel, $\frac{1}{2}$″ diam. octagon, length 6″ ..			6
31	1	3	Woodworker's Vice, 'Record' 8″ (See Fig. 3) ..		15	0
32	1	2	Jeweller's Saw Frame to take fret saws ..		2	6
33	3 doz.	1gro.	Fret Saws for metal .. .. .. (doz.)			4
34	3 ,,	1 ,,	,, ,, ,, wood .. .. .. ,,			4
35	1	6	Hack Saw Frame for 12″ saws		3	6
36	2 doz.	2 doz.	,, ,, Blades 24 teeth to the inch 12″(doz.)		2	3
37	2 ,,	2 ,,	,, ,, ,, 32 ,, ,, ,, 12″ ,,		2	3
38	1	6	File 12″ bastard hand		1	3
39	1	6	,, 10″ second cut hand		1	2
40	1	6	,, 10″ smooth hand		1	3
41	1	6	,, 6″ smooth ,, ...			8
42	1	6	,, 8″ half round second cut			10
43	2	6	,, 6″ round second cut			6
44	2	6	,, 9″ ,, ,, ,, ...			9
45	2	6	,, 6″ square ,, ,, ...			6
46	2 sets	3doz.	Assortment of 4″ small files in sets of six ..		1	9
47	24	7 ,,	Handles, with metal ferrules, selected to fit above files .. . . (doz.)		1	9
48	1	2	Carborundum stone for sharpening wood tools (combination fine and coarse) 7″ × 2″ × 1″ ..		5	3
49	1	3	Round-nose Pliers, $4\frac{1}{2}$″		2	0
50	1	2	Cutting Pliers, $6\frac{1}{2}$″		3	6
51	1	4	Firm Joint Callipers outside 4″		2	3
52	1	4	,, ,, ,, inside 4″		2	3
53	1	5	Toolmaker's Dividers, 6″		5	9
54	1	6	Centre Punch, fine, bright knurled			6
55	1	6	,, ,, medium ,, ,, ...			6
56	1	6	Engineer's Bright Steel Try Squares, Size 3″		2	9
57	1	6	Pocket Scribe			9
58	1	4	12″ Steel Rule, divided inches and millimetres, Chesterman's stainless		2	0
59	1	6	6″ Steel Rule, divided inches and millimetres, Chesterman's stainless		1	5
60	1	2	Hand Saw, 24″, Spear and Jackson		8	0
61	1	3	Tenon Saw, 12″, ,, ,, ,, ...		5	0
62	1	2	Keyhole Saw		3	0
63	1	2	Spare blade for Keyhole Saw			6
64	1	2	Fretsaw frame 12″ (Hobbies)		3	0
65	1	4	Carpenter's Brace 8″, with ratchet		6	0
66	1	3	Brace Bit. Auger $\frac{1}{4}$″		1	3
67	1	3	,, ,, ,, $\frac{3}{8}$″		1	3
68	1	3	,, ,, ,, $\frac{1}{2}$″		1	5



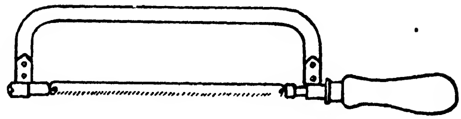
No. 30. Cold chisel



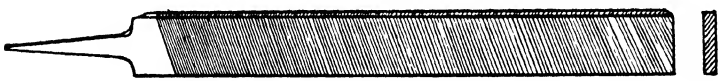
No 48. Carborundum stone



No 32. Jeweller's saw frame



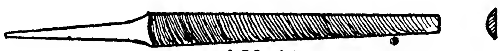
No 35. Hack saw



Nº 38.

Nº 39.

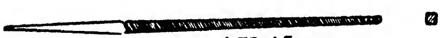
Nº 41.



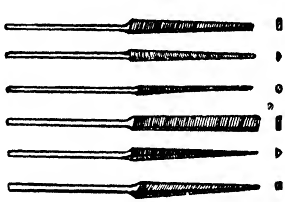
Nº 42

Nº 43.

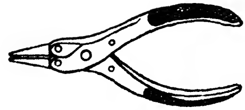
Nº 44.

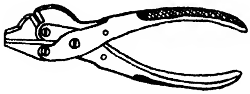


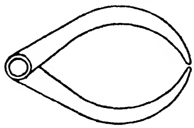
Nº 45.

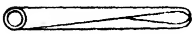


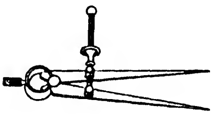
No. 46. Jeweller's files


No. 49. Round-nose pliers


No. 50. Cutting pliers

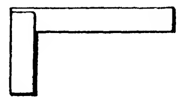

No. 51. Outside callipers


No. 52. Inside callipers


No. 53. Toolmaker's dividers

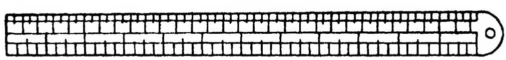

No. 54. Centre punch, fine point

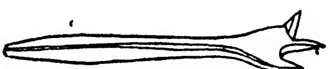

No. 55. Centre punch medium point

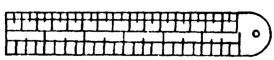

No. 56. Steel try square


No. 57. Pocket scribe

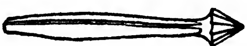

No 66 & 68 Auger bit

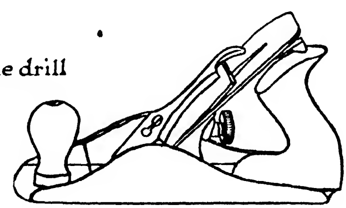


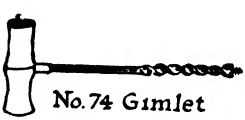

No 69 & 71 Centre bit

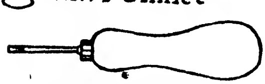

Nos. 58 and 59. Steel rules

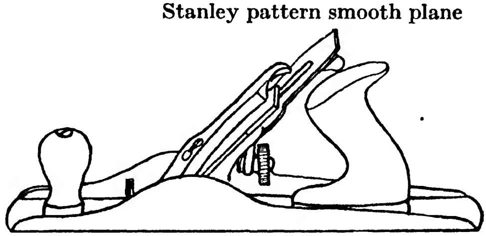

No 73 Countersink for hand or machine drill


No 72 Countersink rose bit


No. 76.
Stanley pattern smooth plane


No. 74 Gimlet

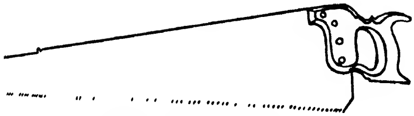

No 75 Bradawl


No. 77. Stanley pattern jack plane

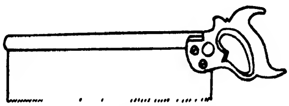
Item No.	No. reqd.	No. reqd. for 12 workers	DESCRIPTION	Approx. Price single tool or set £	s.	d.
69	1	3	Brace Bit Centre $\frac{3}{8}''$			4
70	1	3	,, ,, ,, $\frac{1}{2}''$			4
71	1	3	,, ,, ,, $\frac{3}{4}''$			5
72	2	4	Countersink Brace rose bit $\frac{3}{8}''$			5
73	1	5	Countersink for hand or machine drill. Angle 82°, Shank $\frac{3}{16}$, Body $\frac{3}{8}''$			6
74	1	2	Gimlet (medium size)			6
75	1	3	Bradawl (medium size), with handle ..			6
76	1	3	Bailey or Stanley Pattern Plane, Smooth 9″		7	9
77	1	3	,, ,, ,, ,, ,, Jack $13\frac{3}{4}''$ ..		10	9
78	1	3	Wood Chisel with handle $\frac{1}{4}''$ firmer			8
79	1	3	,, ,, ,, ,, $\frac{1}{2}''$			10
80	1	3	Screwdriver, Cabinet 6″			9
81	1	3	,, ,, 12″		1	9
82	1	3	,, Jewellers'		1	0
83	1	2	Electrician's Turn-screw $\frac{3}{16}''$ point		1	2
84	1	3	Carpenter's Mallet, 18oz.		1	6
85	1	3	,, Square, 9″		3	6
86	1	1	Glazier's Diamond or wheel glass cutter. (See Chap. IX)			
87	1	3	Soldering Iron, 8oz.		1	9
88	1	3	,, ,, 16oz.		3	0
89	1	4	Engineer's Oil Can		1	0
90	1	3	Lancashire Taper Broach, $\frac{1}{8}''$, with handle ..			7
91	1	3	,, , ,, $\frac{1}{4}''$,, ,, ..		1	0
92	1	3	Brazing Lamp for Paraffin, 1 pint, inclined burner. (Not required when gas is available)		10	6
93	1	3	Pliers, long flat nose, 4″		1	6
94	1	3	Firmer Gouge, handled $\frac{1}{2}''$		1	4
95	1	1	Gouge Slip Stone for above		1	8

LIST 'B'

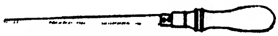
96	1	2	Patent Expansion Drill for Iron Brace shank. (See Fig. 65)		4	6
97	1	1	Combination Square, English and Metric, 6″ ..		12	6
98	1	1	Burner Tap $\frac{3}{8}''$, Screwplate and Reamer. (See Fig. 123)			
99	1	1	High Speed Bench Grinder for Hand. Size of Wheel, 5″ × 1″		5	0
100	1	3	File Brush			4
101	1	1	Spirit Level, 8″		1	9
102	1	1	Sliding Bevel, $7\frac{1}{2}''$		3	0
103	1	2	Spokeshave, Beechwood, Brass Plated on face, 2″		1	6
104	1	1	Plumber's Shave Hook, Triangular			10
105	1	2	Screw Nose Centre Bit for Brace 1″		1	0
106	1	1	Best Black Gas Pliers, 7″		2	0
107	1	3	Wood Chisel with handle, 1″		1	0



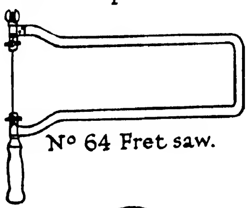
Nº 60 Hand saw.



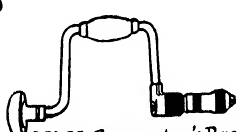
Nº 61 Tenon saw.



Nº 62 Keyhole saw.



Nº 64 Fret saw.



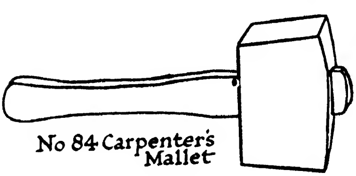
Nº 65 Carpenter's Brace

No 78 Wood Chisel

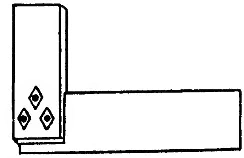
No 80 Cabinet Screwdriver

No 82 Jeweller's Screwdriver

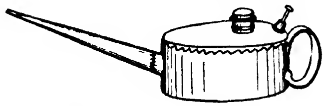
No 83 Electrician's Turn-screw



No 84 Carpenter's Mallet

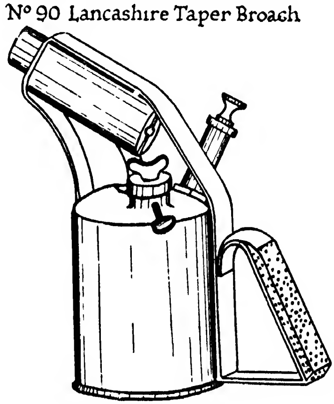


No 85 Carpenter's Square

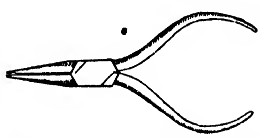


Nº 89 Engineer's oil can

Nº 90 Lancashire Taper Broach

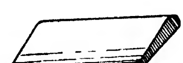


Nº 92 Brazing Lamp

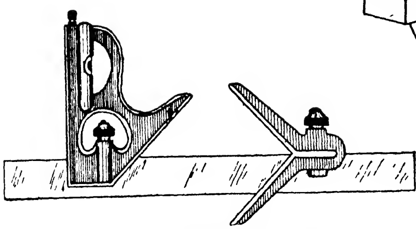


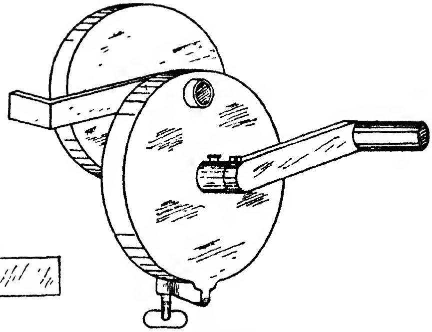
Nº 93 Pliers - Long flat nose

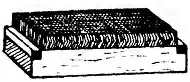
Nº 94 Firmer gouge

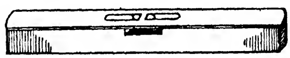


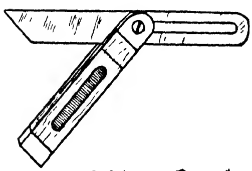
Nº 95 Gouge slip stone


No. 97. Combination square

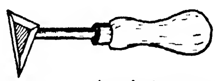

No. 99 Bench grinder

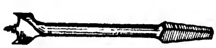

No 100 File brush


No 101 Spirit Level

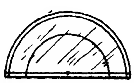

No. 102 Sliding Bevel


No 103 Spokeshave

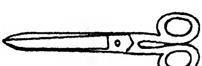

No. 104 Plumber's Shave Hook


No. 105 Screw Nose Centre bit

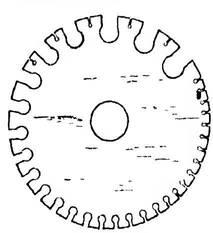

No. 106 Gas pliers


No. 109 Celluloid protractor


No. 108 Nail Set


No. 110 Cutting out Scissors


No. 111 Embroidery Scissors


No. 116. Wire gauge

Item No.	No. reqd.	No. reqd. for 12 workers	DESCRIPTION	Approx Price single tool or set £	s.	d.
108	1	2	Nail Set, ⅛″ tip			6
109	1	2	Celluloid Protractor			9
110	1	2	Scissors, Cutting out, 6½″		4	0
111	1	2	,, Embroidery, Fine Points		1	6
112	1	1	Rawlplug Tool Holder and Bit, No. 8 size. (See Sec. **201**)		1	10
113	1	1	Wall Drill, Size ½″. (See Fig. 295)			6
114	1	1	Box of 100 Assorted Rawlplugs, Size 8. (See Sec. **201**)		2	0
115	1	2	Vice for use in conjunction with drilling machine. (See Fig. 128)		12	0
116	1	1	Circular Imperial Standard Wire Gauge, 1–36		7	0
117	1	1	Mitre Cutting Block. (See Fig. 224) ..		1	0
118	1	2	Twist Drill with bit stock ¼″ (Fig. 212) ..			9
119	1	2	,, ,, ,, ,, ,, ⅜″		1	3

The use of the different tools is fully described in subsequent chapters, but at this stage a few observations on the tools themselves will not be out of place.

Items 1, 2 and 3.

'Little Giant' taps and dies are some of the best tools of this description manufactured. Various Sheffield firms are now making screw cutting tools. 'Little Giant' dies have the advantage of collets that guide the tool and prevent the formation of drunken threads (see Sec. **94** Chapter V).

Dies of this type are made by G. and J. Hall, Hereford Street, Sheffield. Other makers of taps and dies are Joseph Robson and Sons, Mary Street, Sheffield, and the British Tap & Die Co. Ltd., Town Road, London, N.9.

Items 4, 5 and 6. Taps.

Small size taps are liable to get broken. It is useful to keep a few spares in store.

Item 7. Wrenches.

The wrenches obtained should be large enough to turn a ½″ nut.

Item 8. Set of twist drills.

It is worth buying or making a stand. The drills are kept sorted and breakages are instantly detected. Metal stands vary in quality according to the gauge accuracy of the holes provided for the drills. Wooden stands are not recommended, damp or hot conditions soon make the holes inaccurate.

Items 9–16. Extra drills.

It is well to keep some small size drills in reserve, to replace any belonging to the set (Item 8) that get broken.

Item 17. Hand drill.

The 'Yankee' ratchet hand drill No. 1530 is one of the best tools of this description. The ratchet is often a great convenience. A tool without a ratchet, but of English manufacture is the 'Record' hand drill No. 125 made by C. & J. Hampton, Ltd., Sheffield.

Item 18. Drilling machine.

Obtain a substantial machine designed for bolting down to a bench, avoid the type made to clamp to a table edge. Many of the cheap drilling machines on the market have poor bearings and badly cut gear wheels ; before long they develop wear and become inaccurate. The 'Britool' No. 10 machine has all its gear parts enclosed and running in oil, it is made by the British Tool and Engineering Co., Ltd., Wolverhampton, England.

Item 30. Cold chisel.

Moore & Wright, Sheffield, England, make excellent cold chisels in nickel-chrome alloy steel. They are sold under the name of 'Surecut' chisels.

Item 35. Hack-saw frame.

The non-adjustable hack-saw frame is usually more rigid than the adjustable type, unless an adjustable one of first class make be obtained.

A hack-saw frame should hold the blade without any suspicion of side play or twist.

James Neill & Co., Ltd., Composite Steel Works, Sheffield, make a good hack-saw frame known as the 'Eclipse', No. 50. R.S.

Items 38–46. Files.

Files are manufactured in great variety. When ordering files three features have to be taken into account.

1st. The Length. This is always measured exclusive of the tang or part that goes into the handle.

2nd. The Cut. This has reference to the relative degrees of coarseness of the teeth.

3rd. The Name or Kind. This has reference to the shape.

The chief terms used to describe the cut are:—Bastard, Second Cut, Smooth and Dead Smooth.

A bastard file has much coarser teeth than a second cut one and is useful for rough work.

Second cut and smooth files are used when work has to be given a good surface finish.

Dead smooth files are seldom required.

A file with very coarse teeth, designed for filing wood, is known as a rasp.

The shapes of files commonly in use are given (Fig. 19). A flat file differs from a hand one in being tapered at one end.

Fig. 19. File sections

Warding files, apart from other uses, are employed by locksmiths to file the ward notches in keys.

Hand files are made with one narrow side free from teeth. This is known as a safe edge and is useful when the file has to be used in a situation where a slight slip might cause injury to neighbouring work (Fig. 20).

Item 47. File handles.

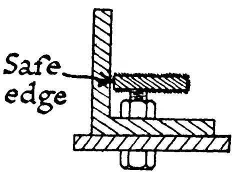


Fig. 20. Use of a safe edge on a file

Files should always be used with handles. When using a file it may catch in the work and an unguarded tang end can, in such a case, give rise to a cut wrist. To fit a handle on a file first make certain that the handle has a good deep hole for the tang to penetrate. If necessary clamp the handle in a vice and using a twist drill, make the hole deeper.

Now clamp the file horizontally in a vice, use jaw protectors, and, with gentle taps, hammer the handle on to the tang. Take great care to drive it on straight. As it is being put on, view it now and again from two positions at right angles to one another.

Item 50. Cutting pliers.

Many cheap cutting pliers have badly tempered cutting edges that soon fail to act. The best pliers are those with a powerful parallel jaw action known as 'Bernard' pliers. These can be used for cutting wire or holding work.

Items 51, 52, 53, 54, 55, 56, 57.

Callipers, dividers, centre punches, try square, scriber. A good

range of Engineers' Precision Tools are now made by Moore & Wright, Sheffield, England.

Item 62. Keyhole saw.

A very good one of improved design is made by the above firm.

Item 65. Carpenter's brace.

Carpenter's braces can now be obtained with jaws capable of holding an ordinary brace bit or a twist drill with straight shank. This is a great convenience in increasing the use of the tool. Twist drills of a size between $\frac{3}{8}''$ and $\frac{1}{2}''$ are liable, if used in a small drilling machine, to press on and injure the springs inside the chuck of the machine. They are readily held in a carpenter's brace furnished with the improved type of jaws.

Items 76 and 77. Planes.

British made planes of Stanley pattern can now be bought. Makers: C. & J. Hampton, Ltd., Sheffield.

Items 78 and 79. Wood chisels.

Marples & Sons, Ltd., Sheffield, manufacture best quality carpenter's tools.

Item 86. Glass cutter.

Notes on the relative merits of diamond and wheel cutters are given in Chapter IX.

Item 89. Oil can.

Moore & Wright make a satisfactory leak-proof oil can.

Item 92. Brazing lamp.

One of the best brazing lamps on the market is that of Primus make.

Item 97. Combination square.

The combination squares of the two American firms Starrett, and Brown and Sharpe are well known to all mechanics for their beautiful finish and smooth action.

Item 99. Bench grinder.

A bench grinder should have substantial, well protected bearings. The Carborundum Company, Ltd., Trafford Park, Manchester, make good machines.

Item 100. File brush.

Sometimes the teeth of a file get clogged up and a file brush is useful for cleaning purposes. Try to avoid using a new file on solder or lead.

Item 104. Plumber's shave hook.

This is a useful tool in a laboratory for scraping benches, removing labels and so on.

Item 115. Vice for drilling machine.

An excellent vice for this purpose is the 'Yankee' No. 990. This opens to 3″ and one jaw has a V groove for holding circular work.

Item 116. Wire gauge.

The usual method of defining the size of a wire is by a gauge number. The British Imperial Standard (abbreviated to S.W.G.) was authorised by Act of Parliament in 1883. A No. 7 S.W.G. wire has a diameter of ·5″, a No. 36 S.W.G. wire has a diameter of ·0076.″

In America another gauge is used known as the American or Brown and Sharpe gauge (abbreviated to B. & S.W.G.).

The following are the names in alphabetical order and addresses of five London tool merchants that issue illustrated catalogues. Some of these catalogues are large, expensive volumes to produce and are only supplied to customers such as colleges and engineering firms, likely to make considerable purchases, but most of the firms publish abridged catalogues of mechanics' and carpenters' tools. Many firms, as already stated, are prepared to give substantial discounts to schools and science workers.

George Adams, 290, High Holborn, W.C.1.
Buck and Hickman Ltd., 2, Whitechapel Road, E.1.
Buck and Ryan, 310–312, Euston Road, London, N.W.1.
R. Melhuish, Ltd., Fetter Lane, Holborn Circus, London, E.C.
S. Tyzack and Son, Ltd., 341, Old Street, Shoreditch, E.C.1.

Some manufacturers will, on request, supply tools direct to customers.

CHAPTER III

MATERIALS

Much time and trouble can be saved by providing the workshop with a small store of suitable materials; it is annoying to be held up in the middle of a piece of work for want of a length of metal of suitable size or for a screw or nut of the correct dimensions and pitch of thread.

It is well to have scrap boxes where oddments of all descriptions can be stored. A good scrap box can be a great aid to the designer and will sometimes save the making of complicated parts. Skilful use of the hack-saw, file and drill will often change apparent rubbish into something quite new and useful.

Electrical contractors and garages frequently have oddments that they are willing to give away or part with for a few pence; for those who live in London, the hawkers' stalls in Farringdon Street and the Caledonian Market, devoted to scrap metal and old instruments, are not, on occasions, to be despised, though they do not always repay a visit.

A scrap box need not be a jumble. Most things can be sorted and arranged methodically. Scrap ebonite in one box, old terminals in another and so on.

In addition to the utilization of old material, a stock of new material should be kept available. The more remote a workshop is from the source of supplies the better should be its store. The metal merchants' lists present a great range of metals in different sizes and shapes.

The metals most commonly used in the construction of apparatus are brass, steel, copper and aluminium; these can be obtained in the form of sheet, rod and tube.

Some knowledge of the different forms and qualities of material, and of the measurements used in commerce is of value to anyone engaged in a workshop.

SHEET METAL

1. Brass.

Brass sheet is sold by weight. The average retail price in England is about 1/– a pound; but it varies slightly with the

fluctuations of the metal market. The quality of sheet brass usually required in a workshop is that known as 'Hard Rolled Brass'. In the thin sizes this is very easy to bend and does so without cracking. From large metal-traders it is possible to obtain other qualities, spring hard, half hard and soft. A small, but sometimes useful supply of spring hard brass can be obtained from the contacts of old flash lamp batteries. Sheet brass is manufactured with a smooth matt, or with a polished finish, the latter is known in the trade as planished brass. When ordering brass it is necessary to specify the area of the sheet required. The stock size of a sheet is $4' \times 6'$. If a whole sheet be not wanted the merchant will always cut off the amount required. The thickness of brass is usually defined, not by actual measurements in inches, but by a gauge number. In England the Imperial Standard Wire Gauge is employed (Item 116 tool list).

Useful gauges are as follows :—

	Gauge No. S.W.G.	thickness ins. app.
Sheet Brass	20	·036
,, ,,	24	·022

Sheet brass in the lighter gauges, can be bought in coils of width $\frac{3}{8}''$ to $1'$. This is a very convenient way of purchasing it.

Recommended gauges in $1'$ widths are :—

	Gauge No. S.W.G.	thickness ins. app.
Sheet Brass rolled in coils	20	·036
,, ,, ,,	22	·028
,, ,, ,,	24	·022
,, ,, ,,	26	·018
,, ,, ,,	30	·0124

A complete coil weights 28lbs., but any smaller amount can be bought. If a large flat piece of brass be required it is better to buy it as an uncoiled sheet and avoid the trouble of having to remove the curvature.

2. Sheet copper.

The method of gauging and selling copper is similar to that for brass. Copper sheet can be obtained coated with a thin layer of tin on one side. This is useful when a copper vessel has to be made for domestic purposes, but it has no special advantages for apparatus construction apart from increased ease in soldering.

Recommended gauge of sheet copper:—

No. 20 S.W.G. Approx. thickness ·036″

The price of copper is about the same as that of brass. A sheet

of brass has greater rigidity than a sheet of copper of equal thickness.

3. Sheet steel.

A useful quality is that known as black, mild steel, sheets No. 16 S.W.G. Approx. $\frac{1}{16}''$ thick. A standard sheet measures 6′ × 24″. A piece measuring 6′ × 6″ is more convenient for cutting up with hand tools than a big one.

4. Tin plate.

This is the material used in the manufacture of cigarette tins, petrol tins and such like. It is thin sheet steel that has been dipped in molten tin to give it a protective coating. It is not sold by gauge numbers; the thickness of tin plate is usually denoted by one or more crosses – one cross – two cross and so on.

Useful thicknesses are two cross and three cross. One cross is very thin, so thin that it can be cut with a pair of strong domestic scissors.

Professional tinsmiths use five cross for first class work, but this is rather thick and difficult to cut and bend without special equipment.

1x	has a	thickness	of	approximately	·0148″
2x	,,	,,	,,	,,	·0164″
3x	,,	,,	,,	,,	·018″
4x	,,	,,	,,	,,	·020″

Tin plate is sold wholesale in wooden boxes holding either 100 thin sheets or 56 when the thickness is greater than three cross. Such large quantities are seldom required in the laboratory workshop. Stock sizes are 20″ × 14″, 25″ × 17″ and 28″ × 20″.

A single sheet of three cross measuring 28″ × 20″ costs retail about 1/3. Most ironmongers keep tin plate for it is largely used in the making and repair of tin kettles and cans.

5. Sheet zinc.

Sheet zinc is very easily bent and soldered and is largely used in the building trade. The manufacturers of sheet zinc use a special gauge not the Imperial Wire Gauge, so it is wise when ordering it to specify the approximate thickness required by stating the latter in decimals of an inch. An advance in the zinc gauge number indicates a thicker sheet, this is the reverse of the S.W.G. numbers, thus –

No. 8	Zinc	Gauge	corresponds	to an	approx.	thickness of	·015″
No. 10	,,	,,	,,	,,	,,	,,	·020″
No. 12	,,	,,	,,	,,	,,	,,	·026″

Zinc is usually stocked by merchants in rolls measuring 8′ × 3′, but small portions can always be bought.

A generally useful gauge is No. 13, Zinc Gauge. This has a thickness of about ·029″ so corresponds approximately to No. 22 S.W.G. (·028″).

An advantage of zinc over tin plate is that, apart from superficial surface oxidation, it does not rust.

6. Sheet aluminium.

The thickness is specified by the use of S.W.G. gauge numbers or in decimals of an inch. Aluminium is very easily cut with a metal piercing saw, hack-saw or snips and is particularly useful in the construction of optical apparatus. It cannot be soldered by ordinary processes, but is readily joined together by the use of rivets or small nuts and bolts. It can be purchased in flat sheets. The stock dimensions of a full sheet are 6′ × 3′. Aluminium sheet is kept by nearly every garage and car-body building shop.

A useful gauge is No. 19, S.W.G. with a thickness of ·040″ or No. 18, S.W.G. with a thickness of ·048.″ A square foot in either of these thicknesses costs about 3 /–. Aluminium sheet of the above thickness has the advantage of rigidity, with lightness and ease of working.

Metal in Rod Form

7. Brass rod.

Brass can be purchased in rod of circular cross section ranging from $\frac{1}{16}$″ up to $2\frac{1}{2}$ diameter.

Useful sizes are	$\frac{1}{8}$″	diam. Approx. cost per foot	1*d.*
,, ,, ,,	$\frac{3}{16}$″	,, ,, ,, ,, ,,	2*d.*
,, ,, ,,	$\frac{1}{4}$″	,, ,, ,, ,, ,,	3*d.*
,, ,, ,,	$\frac{3}{8}$″	,, ,, ,, ,, ,,	6*d.*

When a quantity of brass rod is being ordered it is best to obtain it in lengths of $6\frac{1}{2}$′ ; longer lengths are liable to get distorted during transport. Brass in small diameters can be obtained in the form of wire. This is usually in coils and not suitable when straight lengths of more than a few inches are required. It is very useful for making clamping screws. (See Secs. **85** and **102**). Suitable sizes are $\frac{1}{8}$″ and $\frac{3}{16}$″ diameter wire.

8. Copper rod and wire.

Copper rod is seldom required, it is best to use brass; on the other hand a supply of copper wire known as soft copper wire in

gauges No. 18 and 22, S.W.G. should be available. Soft copper wire, unlike hard copper wire, is readily twisted without breaking. It is useful for binding rubber tube connections to prevent them leaking or slipping off.

9. Steel rod.

Black Mild-Steel Rod. In circular cross section this form of rod is very cheap and in such constant use that a good supply should be kept. It can be bought in any length up to 18′. Six foot lengths are best for store purposes. The following diameters are those most likely to be required.

$\frac{1}{8}''$, $\frac{3}{16}''$, $\frac{1}{4}''$, $\frac{3}{8}''$, $\frac{1}{2}''$.

10. Bright drawn mild steel rod.

Black mild steel rod has a dull, rather rough finish. Mild steel can be obtained in another form known as bright mild steel rod. This has a smooth surface, the diameter is very uniform, having been drawn through dies, and such rod can be used for making axles and other parts requiring an accurate fit. It can well be kept in the sizes given for black mild steel rod.

11. Cast steel ·45–·55% carbon.

It is not easy to cut a perfect screw thread on mild steel. The material is fibrous and tends to tear; a better material to use for the purpose is a quality of steel known in the trade as cast steel ·45–·55% carbon. It costs very little more than mild steel and can be toughened, if necessary, by making it red hot, then plunging into cold water.

12. Silver steel rod.

If a very strong and accurate steel axle be required a length of round, silver steel should be obtained. It is sold in standard lengths 13″ long. Silver steel does not contain any silver; the word silver simply denotes a particular quality of steel. Since silver steel is very hard special care has to be taken when cutting a screw thread on it (see Sec. **93**). Silver steel has approximately 1% carbon and can be made into tools and be hardened or tempered.

13. Meccano axle rod.

Ordinary Meccano axle rod made of steel is very useful. It has a diameter of approx. $\frac{5}{32}''$ and can be obtained in good straight lengths of $11\frac{1}{2}''$. It is soft enough to enable a screw thread to be cut on it without difficulty.

Dw

14. Spokes.

Steel bicycle spokes are approximately No. 15, S.W.G. They are straight and strong. The diameter corresponding to No. 15, S.W.G. is ·073″. On a spoke of this diameter it is possible to cut a No. 9 British Association screw thread.

Umbrella spokes, being of U section, are light and very strong for their size.

15. Wrought iron rod.

Wrought iron is expensive and is seldom used except by shipbuilding and railway works for high class forging.

Many country ironmongers stock so-called wrought iron for sale to farmers and blacksmiths. This is usually a poor grade of small carbon content steel, it can be used instead of black mild steel, but the latter is to be preferred.

16. Metal in flat and square sections.

Lengths of metal with a rectangular section are known as flat rods or sometimes in the thin sizes as strip.

Brass, copper, black and bright mild steel and cast steel can be obtained in this form.

Some useful sections in brass and black mild steel are as follows:

FLAT BRASS ROD

Thickness Breadth	Approx. retail price per foot
$\frac{1}{32}'' \times \frac{1}{2}''$	3*d.*
$\frac{1}{16}'' \times \frac{1}{4}''$	3*d.*
$\frac{1}{16}'' \times \frac{1}{2}''$	5*d.*
$\frac{1}{8}'' \times \frac{1}{2}''$	8*d.*
$\frac{1}{8}'' \times \frac{3}{4}''$	1/–

FLAT BLACK MILD STEEL

Thickness Breadth	
$\frac{1}{16}'' \times \frac{1}{2}''$	This is sold by weight. The approx. price per pound is 10*d.*
$\frac{1}{8}'' \times \frac{1}{2}''$	
$\frac{1}{8}'' \times \frac{5}{8}''$	
$\frac{1}{8}'' \times \frac{3}{4}''$	

Flat copper rod is seldom required. As a general rule brass is to be preferred.

For the connecting strips of potentiometers and Wheatstone bridges copper has a slight advantage. It can be obtained from large metal dealers in all the sizes given for brass.

17. Square, black and bright mild steel and brass rod.

Square section black and bright mild steel can be bought, but are seldom required, on the other hand square section brass has many uses in a laboratory workshop.

The following are suitable sizes to keep in stock.

Square brass rod $\frac{1}{4}'' \times \frac{1}{4}''$; $\frac{3}{8}'' \times \frac{3}{8}''$; $\frac{1}{2}'' \times \frac{1}{2}''$; $\frac{5}{8}'' \times \frac{5}{8}''$.

18. Metal tubes.

Brass, copper and aluminium tubes are readily obtainable in different diameters and thicknesses. What is known as solid drawn tube is manufactured without a join. Brass telescope tubing is so made that the interior is very smooth; it can be obtained in different sizes so that one tube will slide into the other with an easy fit. Broadhurst Clarkson, Telescope Makers, of 63, Farringdon Road, London, E.C.1, often have scrap lengths of telescope tubing for disposal.

The outside diameter is the measurement taken when specifying brass, copper or aluminium tubes. A complete specification involves an approximate thickness measurement.

If brass tubing be not available so called brass curtain tubing will sometimes serve in its place. This is steel tube covered with a thin layer of sheet brass. It is unsatisfactory for screw threading; the screw cutting tool cuts through and peels off the thin coating of brass; a poor untidy thread is the result. Brass curtain tubing is very cheap, it can be obtained in different diameters and it is usually possible to find a size with an internal diameter that will just allow a $\frac{1}{4}''$ diam. rod to slip into it.

19. Solid drawn brass tubing.

Solid drawn brass tubing with an external diameter of $\frac{3}{8}''$ and walls about $\frac{1}{16}''$ thick is very useful for making apparatus utilizing gas fittings (see Secs. **114** and **115**).

The radiator tubes of motor cars are made of copper, this tubing is stocked by most garages.

20. Iron pipes.

Occasionally iron pipes are useful in the arrangement of aquaria and other equipment requiring water. When ordering iron pipes it is well to bear in mind that the diameter used for measurement is the internal diameter and not the external as in the case of brass or copper pipes or tubes.

A half inch iron pipe has an internal diameter of $\frac{1}{2}''$. The external diameter may be as much as $\frac{3}{4}''$.

21. Special sections, angle and channel.

Metal rods having one of the cross sections illustrated (Figs. 21 to 24), are cheap and extremely useful, especially in the following sizes and materials.

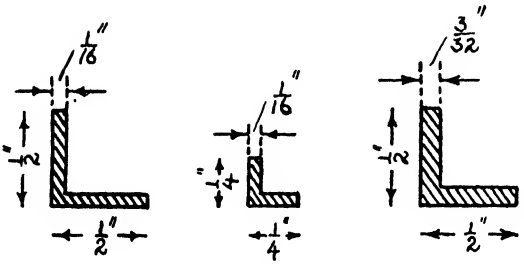


Fig. 21. Angle brass

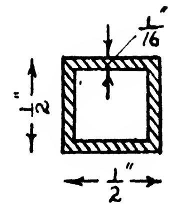


Fig 24
Square brass tube

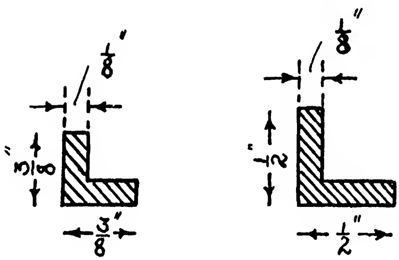


Fig. 22. Angle steel or iron

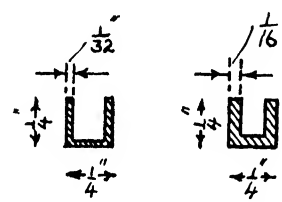


Fig. 23 Channel brass

USEFUL SECTIONS, ACTUAL SIZE

Angle-brass $\frac{1}{2}'' \times \frac{1}{16}''$, $\frac{1}{4}'' \times \frac{1}{16}''$, $\frac{1}{2}'' \times \frac{3}{32}''$ thick (Fig. 21). The $\frac{1}{2}''$ and $\frac{1}{4}''$ refer to the outside measurements

Angle-steel or iron $\frac{3}{8}'' \times \frac{1}{8}''$, $\frac{1}{2}'' \times \frac{1}{8}''$ thick (Fig. 22).

Channel brass $\frac{1}{4}'' \times \frac{1}{4}''$, $\frac{1}{32}''$ thick, $\frac{1}{4}'' \times \frac{1}{4}''$, $\frac{1}{16}''$ thick (Fig. 23).

Channel brass $\frac{1}{4}'' \times \frac{1}{4}''$, $\frac{1}{32}''$ thick will just hold a bound lantern slide and for this reason is of value in the construction of optical lanterns.

22. Square tube.

Square tube made of brass (Fig. 24) is occasionally called for, it is worth keeping a small supply in hand measuring $\frac{1}{2}'' \times \frac{1}{2}''$ and approximately $\frac{1}{16}''$ thick.

23. Screws for metal.

Up to the year 1841 manufacturers of machinery used screws of a size and shape of their own designing, and many different types were in use making the interchange and replacement of parts very difficult. In this year Sir Joseph Whitworth, a well-known engineer, introduced a screw thread, now known as the Whitworth thread that has been generally adopted and is the thread commonly found on the majority of nuts and bolts about a motor car and other heavy machinery.

The shape of the thread is shown (Fig. 25), also the meaning of the dimensions, pitch and depth as applied to a screw thread. Simple mathematical relationships connect the pitch, depth and radius of the curved portions. In this way the exact form of the thread is clearly defined for a whole series of screws of different diameters. The angle 55° and the relationships between pitch, depth and radius remain constant, although the diameter may change. The diameter of a screw is the measurement shown (Fig. 26). It is measured from the top, not the bottom of the thread. A thread cut on a bolt or rod is sometimes known as a male thread and that inside a nut, plate or other fitting as a female thread.

The Whitworth thread was primarily designed for diameters not less than $\frac{1}{4}''$. The form of the thread is such that if made on

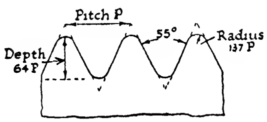


Fig. 25.
A Whitworth thread

Fig. 26.
How to measure the diameter of a screw

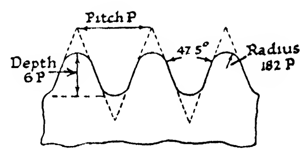


Fig 27.
A British Association thread

a rod of a less diameter than $\frac{1}{4}''$ an undue depth of cut is taken with consequent weakening of the rod, however, for screws not subject to much stress those with $\frac{1}{8}''$ and $\frac{3}{16}''$ diameter Whitworth threads are quite serviceable.

The majority of instruments require many small screws for their construction and for these another thread called the British Association (B.A.), is commonly used.

The form is shown (Fig. 27). It will be noted that the angle differs from the Whitworth thread ($47\frac{1}{2}°$ and not 55°); the relationships between pitch, depth and radius also differ from those used in the Whitworth thread.

If the thread on a Whitworth screw be compared with the thread on a B.A. screw of approximately the same diameter it will be found that the number of threads, or little ridges, per inch on the Whitworth screw is less than those on the B.A. screw, although the depth of thread of the Whitworth screw is greater than the depth of the B.A. one.

The B.A. screw depends for its security and makes up for its lack of depth by a greater number of threads in a given length compared with a Whitworth screw of equal diameter.

A Whitworth screw of $\frac{7}{32}''$ diameter has 24 threads per inch, a B.A. screw of approximately equal diameter has $28\frac{1}{2}$.

Battery terminals, the little screws inside electric switches, in fact in most small electrical apparatus have B.A. threads.

Whitworth (Whit.) threads are defined by the diameter. The sizes most used in a laboratory workshop are:

$$\tfrac{1}{8}'', \tfrac{3}{16}'', \tfrac{1}{4}'', \tfrac{3}{8}'' \text{ and } \tfrac{1}{2}''.$$

British Association (B.A.) threads are defined by numbers. Those most likely to be used are:—

No.	0,	1,	2,	3,	4,	5
Diam.	·236″	209″	185″	·161″	·142″	·126″

A Whitworth nut cannot be fitted to a B.A. terminal or bolt with satisfactory results, although the diameter may be nearly the same. A B.A. nut must be used with a B.A. bolt and a Whit. nut with a Whit. bolt.

Many other threads, apart from Whit. and B.A., are used in the watch, lens, cycle and other specialised industries, but Whit. and B.A. are sufficient for most laboratory workshop requirements.

Special threads are used for gas fittings and iron water pipes. These are dealt with in the sections describing screw cutting (Secs. **114** and **123**).

Nuts, screws and bolts both Whitworth and B.A. can be purchased in great variety.

B.A. nuts, screws and bolts are usually made of brass or steel and Whit. in steel, iron or less commonly brass. The names given to the different shaped heads are indicated in Fig. 28.

When ordering screws for metal it is necessary to specify five things. The thread (B.A. or Whit.), the nature of the head, the material, the gauge number or the diameter and the length. The length of a cheesehead, button head or hexagon head screw for metal is the measurement from just below the head to the end of the threaded part (Fig. 29), but with countersunk head screws the length is overall.

Sometimes a screw is threaded for its whole length and sometimes for part of its length only (Fig. 29).

A screw, especially in the larger sizes is often referred to as a bolt.

An ordinary Whitworth bolt with hexagon head is shown in Fig. 30.

A bolt threaded down its whole length is known as a set screw (Fig. 31).

On motor cars, nuts, bolts and set screws are used made of steel.

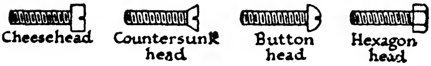


Fig. 28. Screws for metal

Fig. 29. Screws for metal threaded for part of their length only

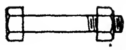


Fig. 30. A Whitworth bolt with hexagon head

Fig. 31. A set screw. The thread extends the whole length of the stem

Fig. 32. Two types of forged or pressed nuts

Fig. 33.

Fig. 34.

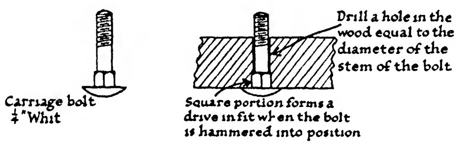


Fig. 35.

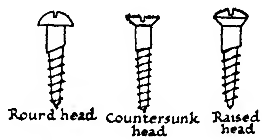


Fig. 36. Wood screws

These are manufactured with beautiful precision by the use of special lathes, they have a bright surface and well-cut threads. They are known as bright steel nuts, bolts or set screws and are of the best quality.

For cheap work, that does not call for such precision and strength, it is possible to buy Whit. nuts and bolts forged from red-hot or pressed from cold steel.

These have a dull black finish and are the nuts and bolts usually stocked by ironmongers. Two types of forged and pressed nuts can be obtained, square and hexagon (Fig. 32).

Two types of nuts that are sometimes useful are wing nuts in iron or brass and turned brass terminal nuts (Fig. 33).

Usually a nut requires a washer under it. Washers are made in black steel, bright steel and brass. Pressed or forged Whit. nuts are usually fitted with black steel washers and bright steel Whit. nuts with bright steel washers of appropriate size. A washer size is specified by the diameter of its hole.

When nuts are subject to vibration and must on no account get loose it is usual to fit them with steel spring washers (Fig. 34).

The washers used with B.A. nuts are made of bright steel or brass and can be obtained in very small sizes.

When fitting a wooden framework together, it is a help to use black steel carriage bolts. These have a square portion under the head and when tapped into a hole of appropriate size in woodwork

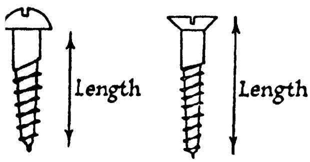


Fig. 37. How the length of a wood screw is measured

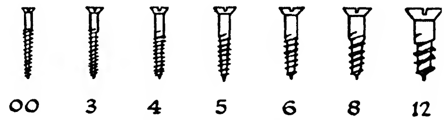


Fig 38. Usual sizes of wood screws

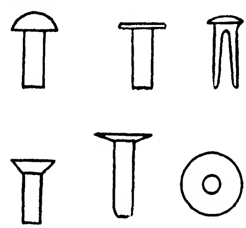


Fig. 39. Types of rivets

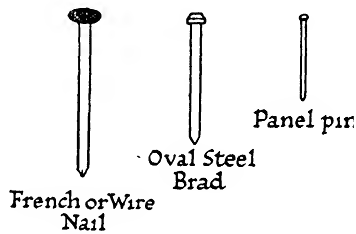


Fig. 40. Types of nails

will not rotate when the nut is tightened (Fig. 35). They are stocked by all ironmongers.

24. Screws for wood.

Screws for wood are made in iron and brass. Brass screws are more expensive and not as strong as iron ones, but have the advantage of not rusting. The heads of screws may be round or countersunk; a type of screw known as a raised head screw has recently come into considerable use for motor body fittings and has a particularly neat appearance (Fig. 36).

The diameter of a wood screw is specified, not in inches but by a gauge number ranging from 0000 or 4 /0 in the very small size then 3 /0, 2 /0, 0, 1, 2, 3, 4 up to 40 (Fig. 38).

To define a screw completely it is necessary to state material, type of head, gauge number and length. A No. 14 screw has a diameter of about $\frac{1}{4}''$, it may have a length of $1''$, $1\frac{1}{4}''$, $1\frac{1}{2}''$, $2''$, $2\frac{1}{4}''$, $2\frac{1}{2}''$, or $3''$, the diameter is constant no matter what the length.

The same note with regard to length and diameter applies to screws of other gauge numbers and diameters. Screws can be

purchased in the small gauge numbers ranging from $\frac{1}{8}''$ long, then in the following steps:—

$$\tfrac{3}{16}'',\ \tfrac{1}{4}'',\ \tfrac{5}{16}'',\ \tfrac{3}{8}'',\ \tfrac{7}{16}'',\ \tfrac{1}{2}'',\ \tfrac{5}{8}'',\ \tfrac{3}{4}'',\ \tfrac{7}{8}'',\ 1''$$

The length of a countersunk screw is the over-all measurement. The length of a round head screw is measured from the underside of the head to the point (Fig. 37). Some useful sizes are as follows:—

Iron countersunk head wood screws.		Brass countersunk head wood screws	
Length		*Length*	
No. 00 $\frac{1}{4}''$	No 6 $\frac{5}{8}''$	No 00 $\frac{1}{4}''$	No 5 $\frac{3}{4}''$
No 3 $\frac{3}{8}''$	No 8 $\frac{3}{4}''$, $\frac{7}{8}''$, $1''$, $1\frac{1}{2}''$, $1\frac{3}{4}''$	No 3 $\frac{3}{8}''$	No. 6 $\frac{5}{8}''$
No 4 $\frac{1}{2}''$		No 4 $\frac{1}{2}''$	No. 8 $\frac{3}{4}''$, $1''$
No 5 $\frac{3}{4}''$	No. 12 $2''$		

As a time-saving guide it is convenient to mount labelled specimens of each of these screws on a board and to hang it up in the workshop with a note below each screw of the correct drills to use with it.

The cheapest way of buying screws is in gross packets. They can also be bought at ironmongers by the dozen. Brass screws cost about twice as much as iron ones of the same type, gauge and length.

25. Rivets.

Rivets in iron, aluminium or copper may be either bifurcated, round or snap head, flat head, countersunk head or hose rivets (Fig. 39). Useful sizes are as follows.

Iron, round head rivets	$\frac{1}{8}'' \times \frac{1}{4}''$, $\frac{3}{16}''$ $\frac{3}{8}''$
Iron, flat head ..	$\frac{1}{8}'' \times \frac{1}{4}''$

Rivets are usually sold by weight.

26. Nails.

Nails are seldom required in the construction of apparatus, it is best to use screws, but occasionally they are wanted, and a few pounds' weight of different kinds should be kept in stock.

Nails are manufactured in many different lengths and shapes.

The three types shown (Fig. 40) should find a place in the workshop store.

French or Wire Nails can be used for fastening together packing cases and other rough work.

The special shape of Oval Steel Brads enable them to be hammered into a piece of wood with little fear of splitting it; they are

very inconspicuous. Panel pins, used for fine work, are of very slight construction.

Wire nails are made in sizes ranging from 1″–7″, oval steel brads from ½″–3½″ and panel pins from ⅛″ to 2″.

Useful sizes are:—

Wire nails, length, 1″, 1½″, 2″, 2½″ Oval steel brads, ½″. 1″, 1½″
Panel pins, ¾″, 1½″

27. Solder.

The solder required for use with an ordinary soldering iron is the grade known as tinman's solder. It is sold by weight in cast sticks about 1′ long.

28. Soldering flux.

This can be made from concentrated hydrochloric acid and scrap zinc (see Sec. **125**).

A very good ready-made flux is 'Baker's Preparation'; this is a fluid and is sold in tins and stoneware bottles. Fluxite, a paste, is supplied in tins of the boot polish type.

29. Combined solder and flux.

'Britinol' paste made by Bi-Metals, St. Mary's Works, Eldon Road, Wood Green, London, N.22, is a combination of both solder and flux. It is sold in tins. When not in use it should be kept with the lid on and before use should be stirred to incorporate any liquid flux that may have floated to the top.

30. Carborundum grinding paste.

A convenient form is a duplex tin. One half of the tin contains coarse paste and the other half compartment fine paste.

31. Carborundum powder.

This is manufactured in many degrees of disintegration. The grade known as 100 is the kind required for general use.

32. Vaseline.

This is best bought in pots. The empty pots are useful for holding small screws.

33. Turpentine.

Obtain this from a reliable paint and colour merchant. Some of the cheap brands of turpentine are adulterated and leave much to be desired. When visiting a paint merchant to buy turpentine

go provided with a clean, dry, corked bottle and buy from his bulk supply.

34. Methylated spirit.

In countries where the tax on methylated spirit makes its use prohibitive and a Primus blow lamp or stove has to be lit, a fairly satisfactory substitute is a mixture of 1 part of paraffin (kerosene) and 1 part of petrol. This of course is not smokeless, but is better and safer than either of the liquids used alone.

35. Plaster of Paris.

This can be bought from a builder, monumental sculptor or at a druggist's. It must be kept dry and is best stored in an air-tight jar.

36. Glass or sand paper.

This is paper treated with glue and sprinkled with powdered glass, sand is less frequently used in these days. It should be stored in a dry place or the glue softens and the glass comes off. If necessary dry it before use. The grade is defined by numbers, 0 is used for very fine work and 2 for rough work.

Useful grades are No. 1, 1½, fine 2 and double 2.

37. Emery cloth.

This is more durable, but more expensive than glass paper. It will tear into strips in one or two directions only. Glass paper is usually used for rubbing down wood and emery cloth for removing rust and polishing metal. Useful grades are: FF, F and 1½. FF has a finer texture than 1½. Both glass paper and emery cloth can be bought in single sheets measuring 12″ × 10″. It is cheaper to buy it by the dozen sheets or by the quire.

38. Scrap celluloid.

This is used for making celluloid varnish and cement. Old celluloid set squares can be utilised, if these are not available celluloid can be purchased from a garage where they do repairs to motor car hoods and side curtains.

39. Amyl acetate.

This is used as a solvent for celluloid. It can be purchased from most drug stores and from all chemical dealers.

40. Shellac.

Shellac dissolved in methylated spirit makes an admirable varnish for wood or for application to insulated wires to act as an insulating and binding medium.

Paint shops keep shellac in dry flake form or already dissolved in spirit.

The solution can be kept in a bottle. It is best to stopper the bottle with a plug of wood; if a cork be used it is very liable to get stuck into the opening by the shellac and breaks when an attempt is made to pull it out.

41. Portland cement.

This can be bought from a builder's merchant. It should be stored in a dry place.

42. Scrap lead.

This can be got from a builder or plumber.

43. Mica.

Small sheets of mica can be obtained from ironmongers who stock anthracite and oil stoves. It is used for the repair of the inspection windows of such stoves.

N.B. Often in commerce wrongly called talc.

44. Rustless steel.

Rustless steel sheet with a polished mirror finish can be bought in large sheets. In thin sizes it can be cut with snips, centre punched and soldered with the same ease as tin plate. It is much harder and more difficult to drill than tin plate. Ordinary twist drills can be used, although if much drilling has to be done, it is best to use specially hardened drills.

A useful thickness is ·024″ (No. 23, S.W.G.). The makers of rustless steel are Thomas Firth & Co., Sheffield.

45. Thin sheet pewter.

This substance is soft and pliable and useful in the construction of scenic models.

It can be bought in sheets of various thickness from most dealers in art workers' supplies.

The average price is 2/– for a sheet measuring 21″ × 15½″.

46. Vulcanised fibre.

Vulcanised fibre, a red coloured substance, a good insulator and tougher than ebonite, can be bought in sheet, rod and tube form.

It is easily cut with a hack-saw, filed and drilled. A sheet measuring $\frac{1}{4}'' \times 6'' \times 6''$ costs about 1/6, and a tube of external diameter $\frac{3}{4}''$ and internal diameter $\frac{1}{2}''$ is sold at $1\frac{1}{2}d.$ an inch. It is stocked by most garages.

47. Investigation of new materials.

One of the interesting features of a workshop is the possibility of studying the properties and possible uses of new materials.

To take one example only: the number of advertised glues and household cements can be counted by the score, a few carefully controlled tests in laboratory and workshop will soon show that only a few satisfy the extravagant claims made for them by the manufacturers.

In recent years many new materials for building engineering and manufacturing have been developed; a science worker, with an interest in practical work, can often benefit by a visit to such exhibitions as The British Industries Fair, London and Birmingham sections, the 'Model Engineer' Exhibition, the Machinery, Building, Shipping and other exhibitions held from time to time.

48. The use of oddments for scientific purposes.

A visit to a 6*d.* store, a marine dealer's store, a cycle accessory or ironmonger's shop can be associated with a new interest if one eye be kept open for the possible use of oddments.

Glass plates sold for table mats make very good plate glass sides for optical tanks. Curtain stretchers of the spring type make potentiometers and flexible steel belts for driving pulleys. Cake tins can be turned into lantern chimneys and tart tins into a stethoscope.

49. The workshop store room.

The following is a list of material suitable for a workshop store.

No. reqd.	DESCRIPTION	Approx. Price £	s.	d.
1 gross	Steel Washers, std. size $\frac{1}{8}''$		1	3
1 ,,	,, ,, ,, ,, $\frac{3}{16}''$		1	3
1 ,,	,, ,, ,, ,, $\frac{1}{4}''$		1	4
1 ,,	,, ,, ,, ,, $\frac{3}{8}''$		1	10
3 dozen	,, ,, ,, ,, $\frac{1}{2}''$		1	0
4 ,,	Bolts and Nuts, Whit. steel, Hex. head, $\frac{3}{16}'' \times 1\frac{1}{2}''$		4	0
4 ,,	,, ,, ,, ,, ,, $\frac{1}{4}'' \times 2''$		5	0
1 ,,	,, ,, ,, ,, ,, $\frac{3}{8}'' \times 3''$		2	0
1 gross	Steel Nuts (Whitworth) $\frac{1}{8}''$		2	6
1 ,,	,, ,, ,, $\frac{3}{16}''$		2	7
1 ,,	,, ,, ,, $\frac{1}{4}''$		2	9

No. reqd.	DESCRIPTION	Approx. Price £	s.	d.
3 dozen	Steel nuts (Whitworth) $\frac{3}{8}''$		1	8
3 ,,	,, ,, ,, $\frac{1}{2}''$		2	0
1, 6′ length	Brass Tube int. diam. $\frac{1}{8}''$		1	6
1, 6′ ,,	,, ,, ,, ,, $\frac{1}{4}''$		2	0
1, 6′ ,,	,, ,, ,, ,, $\frac{3}{8}''$		2	0
2, 6′ lengths	Angle Brass, $\frac{1}{2}'' \times \frac{1}{2}'' \times \frac{3}{32}''$		8	0
2, 6′ ,,	,, ,, $1'' \times 1'' \times \frac{3}{32}''$		9	0
$\frac{1}{4}$lb. coil	Spring Steel Wire S.W.G., No. 22		1	6
1 tin	Carborundum Grinding Paste		1	8
2 lb.	Tinman's Solder		3	0
1 jar	Baker's Soldering fluid		3	0
1 lb.	Glue, Crolid		1	0
3 ,,	Nails Wire, 1″		1	6
3 ,,	,, ,, $1\frac{1}{2}''$		2	0
4 ,,	,, ,, 2″		2	6
1 ,,	Brads, Oval Steel, $\frac{1}{2}''$		1	0
1 ,,	,, ,, ,, 1″		1	0
6, 6′ lengths	Brass Rod, round $\frac{1}{8}''$ diam.		1	6
6, 6 ,,	,, ,, ,, $\frac{3}{16}''$,,		3	6
6, 6′ ,,	,, ,, ,, $\frac{1}{4}''$,,		6	6
2, 6′ ,,	,, ,, ,, $\frac{3}{8}''$,,		6	0
6, 6′ ,,	Cast Steel ·45–·55% Carbon or Bright Mild Steel Rod, $\frac{1}{8}''$		3	0
6, 6′ ,,	Cast Steel ·45–·55% Carbon or Bright Mild Steel Rod, $\frac{3}{16}$in.		3	0
6, 6′ ,,	Cast Steel ·45–·55% Carbon or Bright Mild Steel Rod, $\frac{1}{4}''$		4	0
6, 6′ ,,	Cast Steel ·45–·55% Carbon or Bright Mild Steel Rod, $\frac{3}{8}''$		4	6
3, 6′ ,,	Cast Steel ·45–·55% Carbon or Bright Mild Steel Rod, $\frac{1}{2}''$		4	0
6, 6′ ,,	Flat Black Mild Steel, $\frac{1}{8}'' \times \frac{1}{2}''$		6	0
6, 6′ ,,	,, ,, ,, ,, $\frac{1}{8}'' \times \frac{3}{4}''$		9	0
6, 6′ ,,	,, ,, ,, ,, $\frac{1}{4}'' \times \frac{1}{2}''$		9	0
3, 6′ ,,	Black Mild Steel Rod, $\frac{1}{4}''$ diam.			
3, 6′ ,,	,, ,, ,, ,, $\frac{3}{8}''$,,			
3, 6′ ,,	,, ,, ,, ,, $\frac{1}{2}''$,,			
4, 6′ ,,	Flat Brass $\frac{1}{16}'' \times \frac{1}{2}''$		5	0
4, 6′ ,,	,, ,, $\frac{1}{8}'' \times \frac{1}{2}''$		6	0
4, 6′ ,,	,, ,, $\frac{1}{8}'' \times \frac{3}{4}''$		7	0
4, 6′ ,,	Square Brass, $\frac{1}{4}'' \times \frac{1}{4}''$		7	0
1, 3′ ,,	,, ,, $\frac{3}{4}'' \times \frac{3}{4}''$		5	0
1	Sheet Brass, 4′ × 3′, No. 20 Gauge		8	0
1	Sheet Copper, 4′ × 3′, ,, ,,		8	0
1 dozen	Tin Plate, 1 cross, 28″ × 20″		6	0
1 ,,	,, ,, 2 cross, 28″ × 20″		6	0
1 gross	Button headed metal screws, $\frac{1}{8}''$ diam. × $\frac{3}{4}''$ Whitworth		3	6
1 ,,	Button headed metal screws, $\frac{3}{16}''$ diam. × 1″ Whitworth		3	6
1 ,,	Nettlefold's pressed bolts and nuts, $\frac{1}{8}''$ diam. × $\frac{3}{4}''$ (Round head)		2	3

No. reqd.	DESCRIPTION	Approx. Price £	s.	d.
1 gross	Nettlefold's pressed bolts and nuts, $\frac{3}{16}''$ diam. × 1" (Round head)		2	6
1 ,,	Screws, Brass, Countersunk, ½", No. 10		2	0
1 ,,	,, ,, ,, 1", No. 8		2	10
1 ,,	,, ,, Round head, ¾", No. 8		2	6
1 ,,	,, Iron, Countersunk, ½", No. 10		1	4
1 ,,	,, ,, ,, 1", No. 8		1	6
1 ,,	,, ,, ,, 1½", No. 7		1	8
1 ,,	,, ,, ,, 2", No. 7		2	0
12 sheets	Glass Paper, Fine		2	0
12 ,,	,, ,, Medium		2	0
12 ,,	,, ,, Coarse		2	0
2 tins	Oil, 3 in One (3oz.)		1	8
1 lb.	Copper Wire, Soft, S.W.G., No. 18		2	0
1 ,,	,, ,, ,, ,, No. 20		2	0
1 ,,	Robbialac Black Cycle Enamel		2	0
4 ,,	Aluminium Paint		4	0
4	Robbialac Enamel Brushes		4	0
2 tins	Roscoe Cylinder Black, No. 1 Size. (See Sec. **202** Chapter IX)			

50. Meccano Parts.

The following parts are particularly useful in the construction of apparatus. (Fig. 41.)

No. reqd.	DESCRIPTION	Approx. Price £	s.	d.
2 dozen	Axle Rods, 11½"..		2	4
6 only	Gear Wheels, No. 27		2	6
6 ,,	,, ,, No. 27a		2	6
6 ,,	,, ,, No. 27b		6	0
2 ,,	,, ,, No. 31		2	0
2 ,,	Worms, No. 32			10
4 ,,	Flanged Wheel, No. 20		1	8
2 ,,	Cone Pulley, No. 123		2	6
4 ,,	Pulley Wheel, No. 22		1	0
1 ,,	Contrate Wheel, No. 28			9
1 ,,	,, ,, No. 29			6
1 ,,	Bevel Gear, No. 30			9
1 ,,	,, ,, No. 30a			6
1 ,,	,, ,, No. 30c		1	6
1 ,,	Pulley Wheel, No. 21			4
1 ,,	,, ,, No. 20a			5
3 dozen	Collars with set screws, No. 59		4	6
4 only	Face Plate, No. 109		1	4
1 ,,	Fly Wheel, No. 132		1	8
6 ,,	Couplings, No. 63		2	6
3 dozen	Angle Girders, 9½", No. 8a		6	6
2 ,,	,, ,, 3½", No. 9b		1	4

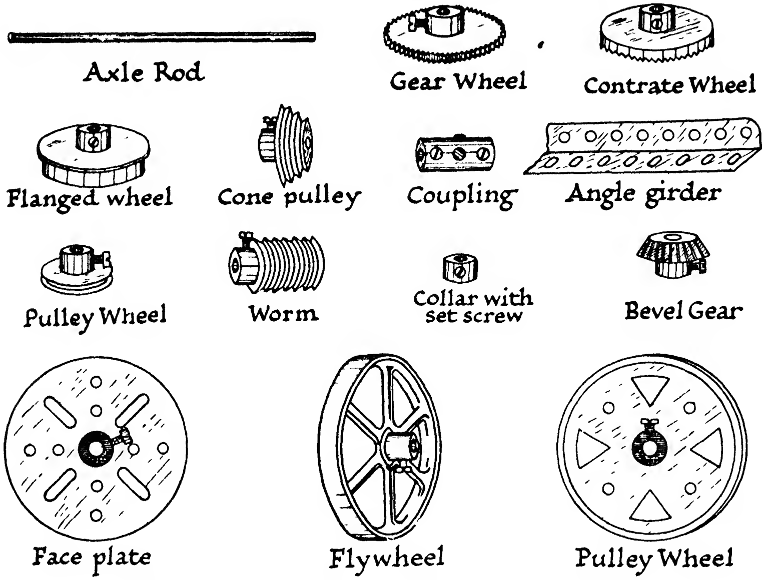


Fig 41. Meccano parts. *By courtesy of Meccano Ltd.*

51. Miscellaneous stores.

Miscellaneous stores should include, boiled linseed oil, turpentine, methylated spirit, vaseline, red lead oxide, scrap lead, shellac, whitening, string, insulating tape, needles, thread and office paste.

52. Dealers in workshop supplies.

The tool dealers mentioned at the end of Chapter II supply materials. It is usually cheaper to buy metal in fairly large quantities than in small lengths or sheets.

Smith & Sons, Ltd., 50, St. John's Square, Clerkenwell, London, E.C.1, are well known to the scientific instrument trade and keep supplies of brass, copper and aluminium in every form manufactured.

Steel of every description can be obtained from Walker Steel Works Ltd., Mary Street, Sheffield.

The following firms issue useful catalogues or price lists, for which a charge of a few pence is usually made:

George Adams, 290, High Holborn, London, W.C.1; Bond's Ltd., 254, Euston Road, London, N.W.1; A. J. Culham, 21, Strathmore Gardens, Romford, Essex; Economic Electric Co., 64, London Road, Twickenham, Middlesex; Grafton Electric Company, 54, Grafton Street, Tottenham Court Road, London, W.1; G. Kennion

& Co., 30, Kingsland Road, London, E.2; Wren Tool Co., 49a, York Road, Ilford, Essex.

Handicrafts Ltd., Weedington Road, Kentish Town, London, N.W.5, issue a 1/- catalogue every year called 'Handicrafts Annual.' It gives the prices and particulars of many useful woodworking materials, such as ply wood, strip wood and dowel rod.

Good second-hand lenses and prisms, including optically worked prisms, achromatic combinations and condensers can be obtained from Broadhurst Clarkson & Co., 63, Farringdon Road, London, E.C.1; also The Miscellaneous Trading Co., Ltd., 13, New Oxford Street, London, W.C.1.

Wray (Optical Works), Ltd., Ashgrove Road, Bromley Hill, Kent, manufacture lenses and prisms of all descriptions and sometimes have surplus material that can be purchased at a reduced rate.

Meccano parts can be bought at most toy shops or from Meccano Ltd., Old Swan, Liverpool.

Other addresses can be obtained from the advertisement pages of the *Model Engineer* and *English Mechanics*.

It is useful to investigate the possibility of local supplies. Many ironmongers and jobbing engineers keep a supply of brass, copper, iron and steel.

CHAPTER IV

HOW TO MARK OUT, CUT, FILE, DRILL AND BEND SHEET METAL, ROD, STRIP AND TUBE

53. How to use metal working tools.

THE art of learning to use tools can be gained in various ways. Some people favour the method of setting students to copy a number of formal exercises before allowing them to construct any definite article. This method is liable to be very slow and dull.

In the experience of the writers it is much better to give even beginners some piece of apparatus to construct and let them learn the use of the different tools as the need for them arises.

The making of quite a simple piece of apparatus will call for the

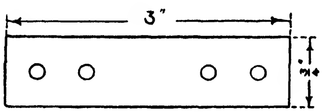


Fig. 42.

Fig. 43.

Strips of metal cut and drilled by a professional and amateur respectively

use of a surprising number of tools and processes and students rapidly acquire skill as the work proceeds.

The materials used in apparatus construction are not expensive and if mistakes are made it is easy to start again after the error of construction has been pointed out.

The chief difference between the work of an amateur and a professional is a matter of degree of accuracy and general finish.

If a professional scientific instrument maker has to construct a strip of metal with four holes drilled in it his finished work may look like fig. 42. The edges of the strip will be at right angles to one another and the holes symmetrically spaced. The work of an amateur may resemble fig. 43, where the edges are not at right angles, and the holes have been drilled at random.

If the beginner will take the trouble to measure carefully and mark out all his work and keep the idea of accuracy ever to the front of his mind it is possible, with a little initial guidance, to produce excellent work almost from the start.

At many of the Board of Education summer courses surprisingly

good work has often been done after a few days' training by men and women with no previous experience of the use of tools.

The writers' method of instruction to a new group of students is to gather them together for an initial talk and demonstration of the use of different tools and after that allow them to start work and come for additional guidance when they feel in doubt. The instructor can with advantage move about the workshop and point out errors or better methods of procedure.

It is suggested that this and other chapters should be studied by the reader, and a general idea of their contents obtained. This done the construction of some piece of apparatus should be commenced and the chapters used for reference purposes when difficulties arise. It is hoped that the system adopted of numbered paragraphs and references in connection with the chapters devoted to apparatus will serve much the same function as a living instructor and enable the reader to acquire rapidly proficiency in the use of tools while engaged in the construction of some interesting and useful piece of apparatus.

None of the processes are difficult and once they have been mastered the reader is in a position to construct a great range of equipment for experimental science.

A complete knowledge of the use of tools, and this applies to tools for working in wood, metal and other substances can only come through the finger ends, but much help can be gained by intelligent observation of the way skilled artisans set about their work. The science worker requires a knowledge of certain parts of many trades and the student can be well advised to cultivate a sympathetic, not a superior interest, in the work of such men. The late Sir Edward Harland, engineer and shipbuilder, used to say how, as a boy, he liked to assist and observe workmen. He got to know every workshop and every workman in his native town and picked up a smattering of a variety of trades, which afterwards proved of the greatest use to him.

54. Marking out strip brass.

Let us suppose that a strip of brass as illustrated (Fig. 42) has to be prepared, it can later be used to make a switch (see page 215). It is possible that a strip long enough for the purpose can be picked out of the scrap box, thus avoiding the cutting up of new material.

If no scrap ends can be found take a long length from the store and place it on the bench. It is possible that one end of the long strip will be square and in good enough condition to use without

further treatment, but usually the ends of store strips are imperfect and have to be cut afresh. This is very often the case with mild steel or iron that has been cut by the metal dealer with a hammer and cold chisel (Fig. 44).

Place a small steel square along the side of the strip. Hold the square firmly to prevent it from slipping and with a steel scriber scratch a line across the brass strip (Fig. 45).

Fig 44.
Metal strip with an imperfect end

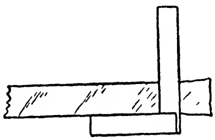
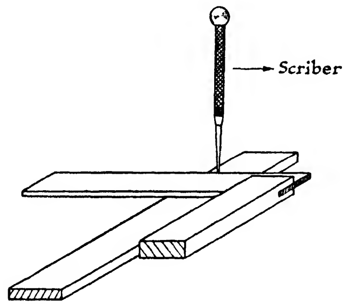



Fig. 45 Method of using a small steel square and a scriber for marking out strip metal

If the strip has to be three inches long take a small steel rule and mark a place 3″ from the first line. With the square and scriber draw another scratch at this place.

55. Cutting strip brass.

The marked length now has to be cut off. This is done with a hack-saw. A hack-saw blade with 22 teeth to the inch is a useful grade to use. The blade must be fixed firmly in its frame and arranged so that the teeth point away from the handle.

The length of brass should be held in a vice and so arranged that the place where the saw cut is to be made is close to the vice jaw. If this be not done the brass strip will bend under the pressure of the saw. Hold the strip so that the scratch mark faces upwards (Fig. 46).

An ordinary steel vice has fine teeth in its jaws and will slightly injure the surface of the brass. One way of avoiding this is to provide the vice with a pair of lead, copper, or fibre clamps to fit over and cover the teeth when delicate work has to be held. Lead and fibre clamps are sold by vice makers, but it is quite easy to make a pair from some sheet copper or even tin plate (see Sec. 73).

Place the blade of the hack-saw on the far edge of the strip and about $\frac{1}{16}''$ away from the mark. Use a finger of the left hand to

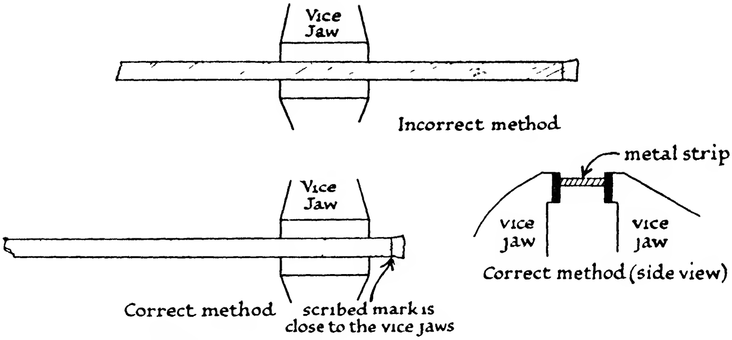


Fig. 46. Incorrect and correct methods of holding a strip of metal in a vice preparatory to sawing

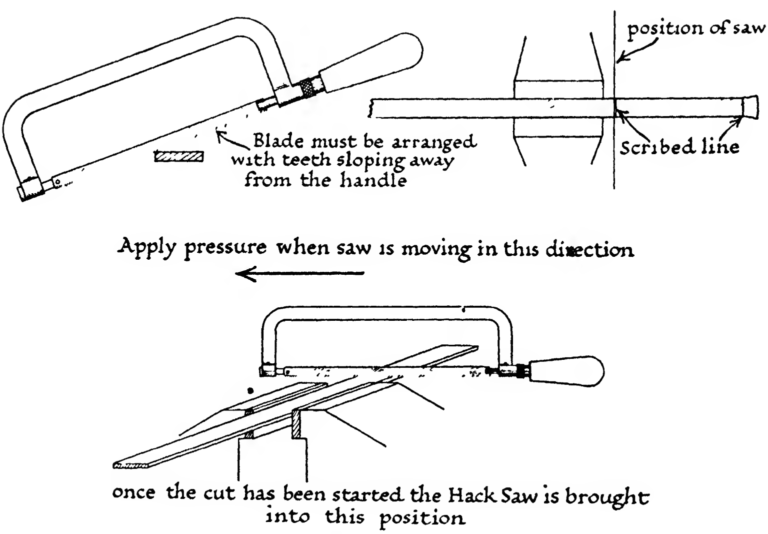


Fig. 47. Method of using a hack-saw to cut strip metal

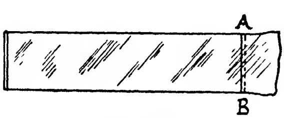


Fig. 48.

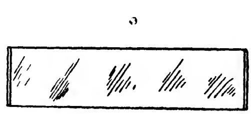


Fig. 49.

Stages in sawing off a strip of metal preparatory to filing to exact length

steady the blade and prevent its slipping about while the cut is being started (Fig. 47).

Once the cut has been started the left hand can be used to grip the forward part of the saw. Apply pressure on the forward stroke only and make about 50 strokes a minute.

Do not twist the saw blade or it may snap in half, since it is made of highly tempered steel.

As the work is nearly cut through go slowly in order to make a clean final cut and to avoid knocking the fingers by a sudden collapse of the saw frame downwards.

When a long strip of metal is held in a vice in this way it is advisable to get someone to hold the long end or otherwise support it. Less force is then needed to hold the strip in the vice and the unused length does not suffer distortion.

Remove the long length. The marked length will now appear as (Fig. 48).

Grip the marked length in the vice with the line AB close to the jaws, and with the hack-saw used as before make a cut about $\frac{1}{16}''$ to the right of the line. These processes provide a length of brass as shown (Fig. 49). The next thing is to file it to the exact length required.

56. Filing strip brass to size.

Grip the strip vertically in the vice with one of the ends projecting about $\frac{1}{4}''$ above the vice jaw (Fig. 50) and with a flat second cut file, file each end in turn down to the mark. File work requires care. Use the file with a steady movement, and try to avoid rocking the tool or the work will become rounded. Hold the handle in the right hand, grip the far end with the left hand or left fingers and apply pressure on the forward stroke only.

When brass is being filed in this way difficulty is sometimes caused by a burr obscuring the view of the mark. To avoid this, when nearly down to the mark lift the file clear after each forward stroke. Another way is to grip the strip by its narrow sides and file down to the mark as shown (Fig. 51). This avoids all trouble due to burr and careful watch can be kept on the accuracy of the work. Steady the file and help to apply pressure by pressing on its far end with the fingers of the left hand.

57. Drilling strip brass.

Before holes are drilled their positions should be carefully measured out and marked. This is most important if good finished work is to be produced.

Mark out with the help of a steel rule, a scriber and a small steel square.

Strip brass has a smooth surface and is easily and clearly marked with light scratches that can be subsequently removed by a little polishing with fine glass paper. Suppose the 3″ strip of brass has to be drilled as shown (Fig. 52) mark the lines AB, CD, EF, GH and IJ using a rule, square and scriber. The centre of AB and IJ required for drawing a centre line can be found by applying the millimeter edge of the rule to these lines. When the centres have been found they must be punched before drilling or the point of

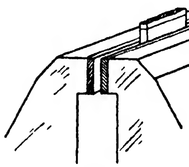


Fig. 50. Strip of metal ready for filing to scribed line

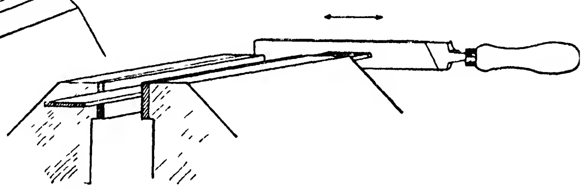


Fig. 51. A method of filing that avoids the formation of a burr over the scribed guide line

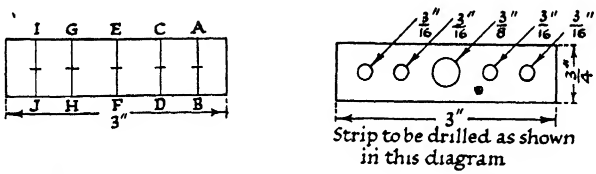


Fig. 52. Method of marking out a strip of metal before centre-punching and drilling

the drill will wander about and not pass through at the exact place required.

For centre-punching use a punch with a fine point, put the work on some non-yielding surface to serve as an anvil (Fig. 53), place the point of the punch on each of the centre marks in turn and give the top of the punch a sharp blow with a ½lb. hammer. This has the effect of making a tiny dimple at each of the marks.

A useful anvil is provided by a short scrap length of iron girder to be obtained for a few pence from a builder or scrap iron merchant. An ordinary domestic iron used upside down with its handle fixed on a block of wood or gripped in a vice also makes a good surface to centre punch on.

Drill the holes with twist drills held in a hand drill or placed in the chuck of a drilling machine. It is much less tiring to drill

metal using a small drilling machine than a hand drill if the work is more than $\frac{1}{16}''$ thick.

The hand drill specified in the list of tools will take twist drills up to $\frac{1}{4}''$ and the drilling machine up to $\frac{1}{2}''$.

Care must be taken when using drills larger than $\frac{3}{8}''$ in the chuck of the drilling machine to avoid crushing the three little springs inside. The writers prefer to avoid the possibility by holding such drills in the chuck of a carpenter's brace adapted for the purpose (see note, Item 65 tool list). When using a hand drill care must be taken to keep it vertical. This is less important with thin than with thick work.

Place a piece of wood under the work to be drilled to serve as a protection to the bench top and carefully place the point of the drill in a centre punch impression before starting to turn the handle. The impression serves as a guide and by preventing the drill from wandering about ensures the hole being made in the correct place.

If the work tends to fly round with the drill, drive one or two nails into the wooden drilling board or fix a strip of wood on it. This will stop the work from turning.

When a drill bit has nearly passed through a piece of metal it will sometimes take an extra deep cut and bind in the work, and if care be not taken the drill bit, especially if it is a fine one, may be broken.

To avoid this, use the hand or machine drill with extra care when the drill bit is nearly through.

If necessary turn the handle backwards, then gradually work it in the forward cutting direction again. A hand drill fitted with a ratchet is particularly useful when a drill bit is tending to bind. Under such circumstances it is often difficult to keep on turning the handle round and round; if the ratchet mechanism be put into action the handle can be given a slight to and fro movement and the drill bit can be gradually fed forward.

Another way of getting over the difficulty is to reverse the work and file off the elevated portion made by the penetrating drill-bit. This will make an opening for the point of the drill-bit when little difficulty will be experienced in completing the drilling process.

58. Drilling large holes.

If the work has been carefully centre punched before drilling is started little difficulty will be experienced in making small holes in correct position. Large drills are not so readily guided by a centre punch mark, and sometimes to ensure accuracy it is better

to start by drilling a small hole right through the work to serve as a guide for the larger drill. In the case of the piece of work under review (Fig. 52) before attempting to drill out the central $\frac{3}{8}''$ diam. hole, drill a guide hole of about $\frac{1}{16}''$.

Another advantage of using a guide hole in connection with large drills is that the cutting edge of the large drill obtains more purchase and the rate of drilling is greatly increased. This is very marked when iron or steel is being drilled.

59. The general use of twist drills. Use of oil.

Twist drills are not only used for drilling brass but all metals, also ebonite, fibre and wood. When drilling brass, copper, ebonite, fibre or wood the drill can be used without oil, but in the case of iron and steel a few drops of oil, motor car engine oil, should be put at the place of drilling just after the drill bit has been started on the centre punch hole.

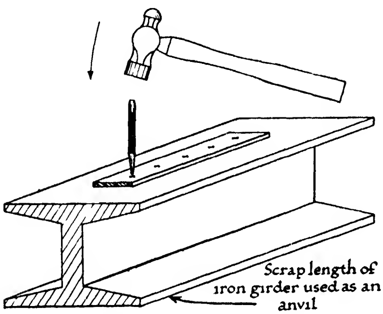


Fig. 53. Method of centre-punching a strip of metal before drilling

If a piece of thick iron or steel is being drilled extra oil may be necessary as the work proceeds.

Always centre punch metal, ebonite and fibre before drilling. This is a great aid to accurate work.

60. Drilling square brass.

When making a brass clamp as shown in fig. 326 it is necessary to drill a $\frac{1}{4}''$ diam. hole through a piece of $\frac{3}{8}''$ square brass. To do this, carefully mark out the exact positions of the hole with a scriber and centre punch the opposite faces of the work (Fig. 54).

Start by drilling a $\frac{1}{16}''$ diam. hole right through the work. If this be done in one operation, from one side only, the drill will probably get crooked and come out on the opposite face at a place away from the centre punch mark, so it is best to drill half through from one side and half through from the other, the two small holes meeting at the centre. If this hole is being made with a drilling machine, rest the work on the iron bedplate of the machine in order to get a good support; care must be taken so to arrange the work that each end is supported. If the piece of brass is short it may be necessary to unclamp the drill and swing it over

a little to one side so that the end of the work nearest to the hole will have a support (Fig. 55).

If a drilling machine be not available take great care when doing work of this kind with a hand drill to keep the tool vertical. Sometimes it is a help to get a friend to view the tool from two positions at right angles and say when it is vertical and correct for drilling, and to check the position as the drilling proceeds. The work can be conveniently held in a vice, but care must be taken to clamp it accurately, the top edges being flush with and parallel with the vice jaws.

One method of giving support to work on a drilling machine is to rest it on a block of wood. If this be done use a block of hard wood such as oak, when thick work has to be drilled, otherwise the pressure of the drill will force the work into the wood and the drill hole will become inaccurate (Fig. 56).

Once an accurate small hole has been made it is an easy matter to drill the hole full size. This can be done from one side only, the small hole will act as a guide.

When a hole has to be drilled in one side of a block of square brass, first locate the centre by scribing diagonals and centre punch the position. The block can either be held in a bench vice and drilled with a hand drill, or clamped in a machine vice and drilled with the bench drilling machine. In either case care must be taken to clamp it vertically.

61. Cutting circles, slots and other holes in thick metal, using a drill and files.

Thin metal can often be cut with snips (see Sec. 63), but this method cannot be used with metal that is much over $\frac{1}{16}''$ thick.

To cut a circle in thick sheet metal plate first locate the centre of the circle and centre punch it with a fine punch.

Open out a pair of steel dividers to the required radius, and placing one point in the centre punch hole describe a circle (1 Fig. 57). The steel dividers will scratch a circle on the metal. Now describe a second circle of $\frac{1}{16}''$ smaller radius (2) after making a number of centre punch marks on this (3), drill cut a series of $\frac{1}{8}''$ diameter holes (4).

Place the work on a block of iron to serve as an anvil (see Sec. 57) and with a small cold chisel and hammer cut the metal between the holes (5). The centre can now be removed.

Clamp the metal plate in a vice and using jaw protectors, take a half round second cut file and file down to the outer marked circle. As filing proceeds, unclamp the work and turn it from

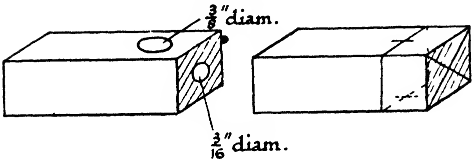
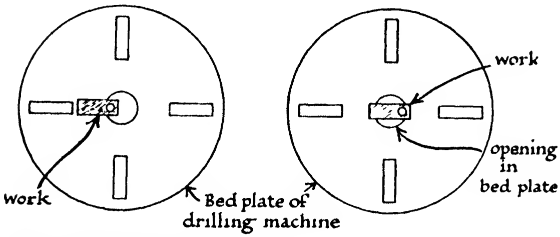


Fig. 54.
Method of marking out a piece of square section brass preparatory to drilling



Work incorrectly supported, it is liable to tilt

Work supported at both ends and so arranged that the drill on passing through will not cut into the bed plate

Fig. 55. Incorrect and correct methods of arranging work on the bed plate of a drilling machine

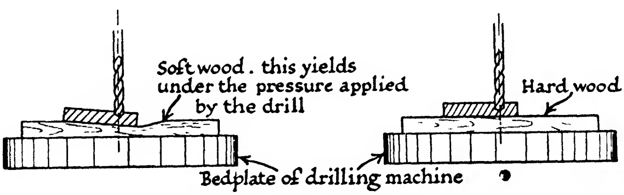


Fig. 56. When drilling a strip of metal near one end, support it on a piece of hard wood

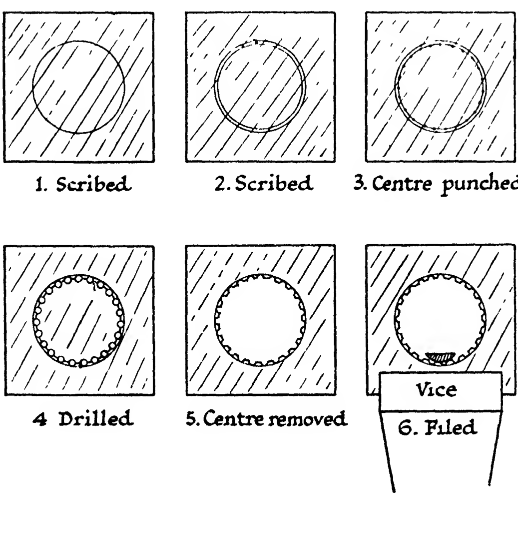


Fig. 57.
How to cut a circular opening in a sheet of thick metal

time to time so that the part being filed is always close to the top of the vice jaws and has plenty of support (6).

62. To cut a slot or square hole in thick sheet metal.

The method of drilling and filing described for cutting out circles is applicable to slots, square holes and other openings.

63. Cutting thin sheet metal.

Thin sheet metal, tin plate, copper, zinc, aluminium, brass and mild steel are readily cut with a pair of tinman's snips. These are used like a pair of large scissors. The larger the snips the greater is the leverage obtained and relatively easier becomes the work of cutting. For small work large snips are clumsy and less accurate in use than small ones.

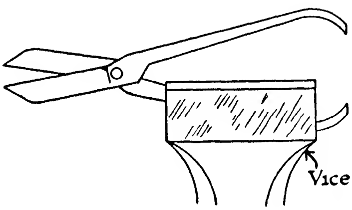


Fig. 58. Method of clamping snips in a vice to obtain extra leverage when cutting thick metal

With large snips it is sometimes difficult to cut close to an edge, the metal tending to turn over. When marking out it is worth bearing this in mind, and keep all marking out lines at least $\frac{1}{2}''$ away from any edges.

The handles of snips come together at the end. Keep the fleshy part of the hand away from the end, or the skin may be pinched. Extra leverage can be obtained by clamping one handle of the snips in a vice. If the sheet to be cut be pushed well up between the jaws of the snips, close to the fulcrum and pressure be applied to the far end of the movable handle quite thick metal can be cut with small snips.

64. Flattening sheet metal.

If a sheet of metal has got bent and requires flattening this is readily done by placing it on a flat bench top or on the floor and by beating it out with a wooden mallet. If a wooden mallet be not available the process can be carried out with an ordinary hammer, but, in this case, unless care be taken, the surface of the metal is liable to be disfigured by hammer marks. A simple and effective

way out of the difficulty is to hammer a small block of hard wood that is moved about over the raised portions of the sheet of metal.

65. Marking out sheet metal.

Sheet metal can be marked out with a scriber, a steel rule and a square.

Usually a sheet of metal taken straight from the store has at least one straight edge that can be used to mark out from, but if none of the edges are straight, start by scribing a straight line with a steel rule and cut along this line with snips. Once a straight base line has been obtained other lines can be easily scribed out.

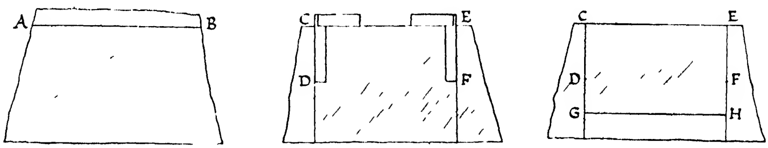


Fig 59.
This shows stages in scribing and cutting out a rectangle in sheet metal

Lines at right angles to the base can be marked with the help of a small engineer's steel square, a large carpenter's square or a T square, according to the size of the rectangle that has to be set out.

Figure 59 shows stages in scribing and cutting out a rectangle.

(1) Mark a straight base line AB and cut along this line.

(2) Mark C and E at distance CE = one side of rectangle.

(3) Using a square scribe lines CD and EF. If a large rectangle has to be marked out it is best to use a large carpenter's square or a T square for marking these lines.

(4) If necessary, by using a steel rule, extend CD and EF to G and H. Make CG = EH = required length of side of rectangle. Check the accuracy of the marking out by measuring the length of the diagonals and finding if they are equal.

Cut out the rectangle with snips. Do not attempt to cut along CG and turn the corner to cut GH, but cut straight across the whole sheet along CG and remove the left hand portion. Make the other cuts in the same way.

66. Cutting difficulties.

Sometimes when sheet metal is being cut the scrap will curl around the snips and make it difficult to work them (Fig. 60). If this happens stop cutting along the guide scratch and snip off and remove the curling portion of waste metal.

67. The storage of scrap sheet metal.

Scraps of sheet metal, unless of very irregular shape, can well be kept in a scrap box for possible future use. Before storing scrap metal it is wise to trim it up roughly, if this be not done it tends to get in a tangle and become difficult to sort out.

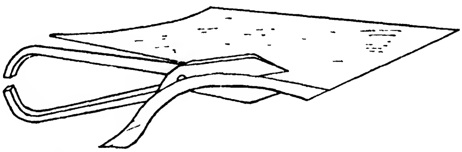


Fig 60 A cutting difficulty. The scrap metal may curl around the snips

68. Cutting circular work.

A good example of circular work is the construction of a sheet metal collar to fit over a lens, to serve as a shield for cutting out strong light.

Suppose a collar of the dimensions shown in fig. 61 (a) has to be made. First determine the diameter of the lens by measuring the lens mount with a pair of external callipers (c). When taking such measurements it is convenient to work in cms. and mms.

Read the calliper opening by application of the tips to a steel rule. Set a pair of steel dividers to the required radius.

Place the sheet of metal to be marked on a flat surface and centre punch an impression for one point of the dividers. This will prevent the tool from slipping when describing a circle on the sheet metal. Describe the circle for the lens opening and the outer circle.

A circle of 6″ radius can be cut out with straight snips, circles of small radius are more easily cut with curved snips (Item 23 tool list).

A circular disc having been cut the next thing is to remove the inner circle. If the metal is tin plate the snips are liable to produce a sharp edge and before proceeding to cut the inner opening it is a good thing to rub off the sharp edge of the disc with a small wad of glass paper or emery cloth made by folding a strip several times over.

This will leave the disc in a comfortable condition to hold.

Place the disc on an anvil and with the help of a cold chisel and hammer cut an opening for the insertion of a pair of small curved snips (b). Cut along the dotted line and so remove the central circular portion: smooth the edge with glass or emery paper and

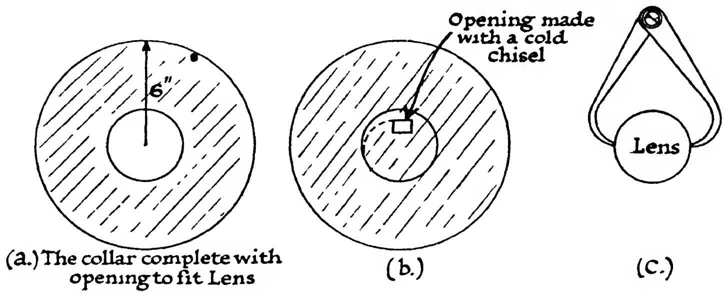


Fig. 61. The construction of a sheet metal collar to fit round a lens mount

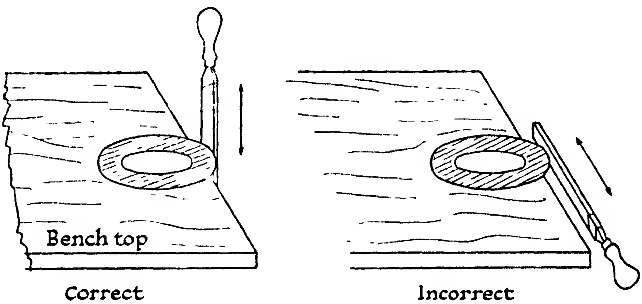


Fig. 62. Fig. 63.

Correct and incorrect methods of filing the edge of a disc

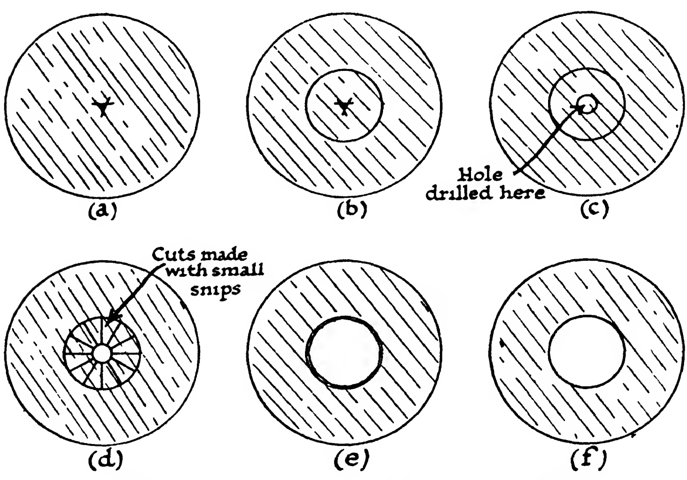


Fig. 64. Stages in cutting an opening in the base of a tin can to take an electric lamp holder

try the fit of the collar on the lens mount. If the opening be not quite large enough, grip the disc in a vice and file it evenly all round with a second-cut, half-round file. Change the position of the disc as the filing proceeds, so that the portion being worked on is always near the jaws of the vice and has plenty of support.

Instead of using a vice the disc can be placed flat on the bench top with the inner opening projecting sufficiently over the edge to enable a file to be inserted and worked up and down.

File with care or too much metal may be removed, or removed unequally. Every now and again try the fit of the collar on the lens.

The method of placing the disc flat on a bench top and filing may be used to smooth the outer edges of the collar. If done in this way, instead of using glass or emery paper, take care to work the file up and down at right angles to the surface of the disc (Fig. 62). If used as shown (Fig. 63), the file may slip and the metal disc is then liable to cut the wrist.

69. To decrease the size of a circular opening in a disc.

If an opening has been cut or filed too large it can be made smaller by placing the sheet of metal on an anvil and hammering all round the edge of the opening. This has the effect of spreading the metal.

70. To cut an opening in the end of a tin can for an electric lamp holder.

Measure the diameter of the lamp holder with callipers (see Sec. **68**). Find the centre of the tin can. This can be done with a pair of dividers. Support one point of the dividers on the edge of the tin, if necessary holding it in place with a finger. Open the dividers out to approximately the radius of the tin. Describe an arc, scratching a mark on the tin. Move the dividers and describe two more arcs. The intersection of the arcs enables the centre to be located fairly accurately (Fig. 64a).

Place the tin over a block of wood held in the vice and put a punch mark at the centre.

With dividers set to the radius of the lamp holder describe a circle on the tin (b), using the centre punch mark as a support for one leg of the dividers. Drill one or two adjacent holes close to the centre large enough to enable small straight snips to be inserted (c).

Make a series of radial cuts up to the circle (d) and by bending the little strips so produced backwards and forwards they can be broken off, thus leaving a roughly circular opening (e).

A little filing with a small, half round second cut file will make the opening smooth and truly circular (f).

71. To cut holes with a circle cutter.

A very useful tool for cutting circular holes in sheet metal is depicted (Fig. 65).

The tool is held in a carpenter's brace. The metal to be cut is centre punched, drilled at the punch mark with a $\frac{1}{16}''$ hole and placed on a piece of flat board. The cutting part of the tool is set to the required radius and when rotated with the drill point of the tool placed in the centre hole, a clean circle can be readily cut out of quite thick sheet metal.

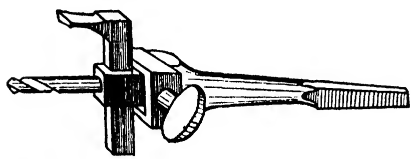


Fig 65. Expansion drill for cutting large circular holes in sheet metal
By courtesy of Buck & Hickman Ltd

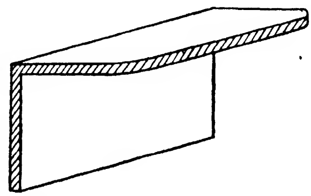


Fig. 66. Vice jaw clamp. Two are required for each vice

As a general rule it is best to cut half way through from one side, remove the work, then complete the cutting from the opposite side. If this be not done, the metal is sometimes liable to tear.

72. Bending sheet metal.

This is a workshop process that is often required and can be accomplished in various ways.

The following examples will serve to illustrate different processes.

73. Vice jaw clamps. (Fig. 66.)

These are pieces of metal to fit over the serrated surface of the vice jaws and serve to protect work held in the vice from being marked.

To make a pair of metal clamps mark out and then cut with snips two rectangular pieces of sheet copper or tin plate measuring about 2″ wide and of a length corresponding to the length of the jaws.

If the vice has 4″ jaws make the pieces 4″ × 2″. Grip one of the pieces in the vice and hammer it over with an ordinary hammer to conform to the top surface of the vice.

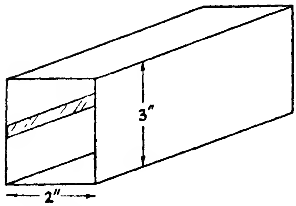


Fig. 67. A rectangular section tube

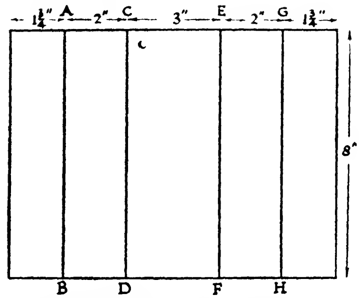


Fig. 68. Sheet of metal marked ready for bending into a square section tube

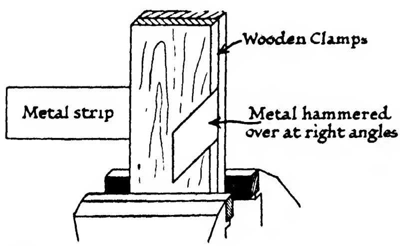


Fig. 69. How to bend the metal for making a rectangular section tube

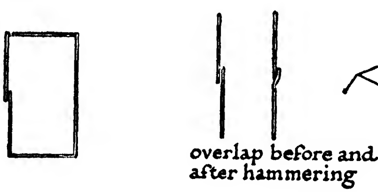


Fig. 70.

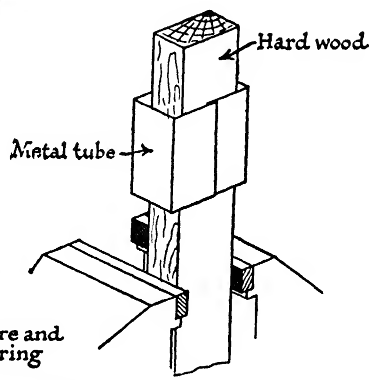


Fig. 71.

Treat the second piece in the same way.

Round off the corners with a file.

Copper and tin plate can be bent over at an abrupt right angle in this way without fear of cracking. Soft brass and zinc can be similarly treated, but hard brass in sizes greater than $\frac{1}{16}''$ thick is liable to crack if hammered over at a sharp angle.

74. Making a rectangular section tube. (Fig. 67.)

This can be used in the construction of a small reflecting galvanometer lamp or parallel beam apparatus.

Materials. Sheet copper, brass, zinc or tin plate.

Cut a sheet of metal measuring $10\frac{1}{2}'' \times 8''$ and scribe the lines AB, CD, EF and GH (Fig. 68). Obtain two pieces of hard wood, planed to rectangle form and measuring about $\frac{1}{2}''$ thick, 10″ long

and a little under 2″ wide. Clamp these in the vice with the metal to be bent so arranged that the line GH or AB just shows along one side. Use a wooden mallet and hammer over the short projecting piece at right angles to the remainder (Fig. 69).

Construct each of the sides in the same way taking care that the metal does not slip during the hammering over process. The first blows in each case, should be directed with care and the guide line examined now and again to make certain that the bend is being made at the correct place.

The sheet of metal when completely hammered over will have a section resembling fig. 70. Slip the tube over a length of fairly hard wood clamped in the vice, and with the narrow end of a hammer give a series of smart blows to the overlapping portions of metal. This has the effect of shaping the metal so that the two portions are brought into the same plane (Fig. 71). The joint is then soldered together (Secs. **125** and **126**).

75. Construction of a chimney cover for a lantern. (Fig. 72.)

Materials. Brass, Copper or Tin Plate.

This chimney cover is in effect a rectangular metal box.

Scribe and cut out a sheet of metal as shown (Fig. 73). Place the cut out metal on the bench and hold a small rectangular block of wood with its edge along one of the inside scribed lines (Fig. 74), bend up the end portion ABCD. This can be done by starting the bend with the fingers and then hammering the side into a vertical position with a wooden mallet. With a little care and by keeping the edge of the block on the guide line a good bend can be effected.

Treat each of the sides in the same way.

Tap the corner edges into close contact, then run solder along them from the inside. Sharp outside edges and corners can now be rounded off with the help of a file and fine glass paper.

76. Additional methods of bending sheet metal.

From the scrap heap of an engineer or builder who engages in structural metal work it is often possible to obtain short lengths of steel girder of an L or T section that make admirable anvils for the bending of sheet metal. These lengths can be held in a vice.

A useful home-made aid to sheet metal work consists of two strips of rectangular section mild steel measuring $12'' \times 1'' \times \frac{1}{4}''$ (Fig. 75).

A series of $\frac{1}{4}''$ diam. holes are drilled in corresponding positions in each of the strips. Metal to be bent is clamped between the strips by a couple of $\frac{1}{4}''$ diam. steel nuts and bolts passed through

two of the holes. The strips can be held securely in a vice during the hammering and bending over of the metal

77. Treatment of edges.

The edges of sheet copper, brass, zinc and aluminium can be rounded by filing and rubbing with glass paper. Tin plate is not so easily treated and sharp edges are unpleasant.

If the lantern cover be made of tin plate it should be marked out as shown (Fig. 76), an extra $\frac{1}{4}''$ being allowed all round. The edges should be bent up at right angles along the $\frac{1}{4}''$ lines then hammered over as shown (A and B, Fig. 76). The initial bend at right angles can be made over the edge of an anvil or, with the help of clamps, turned up in stages by working along the line with a pair of flat nosed pliers. The first two methods are preferable. The turning over of the edges gives extra strength and yields a smooth edge. The edges having been turned the sides can be bent up and the cover completed as already described.

78. Construction of a tube.

Sometimes a tube is required for the construction of a solenoid or an electro-magnet.

If a piece of ready-made tube be not available a satisfactory substitute can be made from thin sheet metal. Obtain a piece of wood of circular section of the required inside diameter of the tube. A length of dowelling is often suitable. Cut a piece of sheet copper, or brass of a width equal to the required length of the tube, but two or three inches longer than the circumference of the rod. On this scribe two parallel lines, one at a distance from an edge equal to the circumference of the rod and the other at a distance $\frac{1}{4}''$ greater than this (Fig. 77). The extra $\frac{1}{4}''$ provides for an overlap.

Place the rod on the metal and by finger pressure and blows from a hammer curve the metal round the rod. The extra 2″ or 3″ of metal is a help in carrying out this process. When the metal has been curved almost round the rod, cut along the scribed line AB with snips and complete the formation of the tube by hammer blows. Finally, with black iron wire, bind the overlap edge into close contact with the rest of the metal, remove the wooden rod and run solder along the joint (Secs. **126** and **127**). Take off the binding wire and clean up the joint with a file and emery paper.

79. To cut an opening in the side of a tin can.

A circular opening or a slot is sometimes required in the side of a tin can for the construction of a light shield.

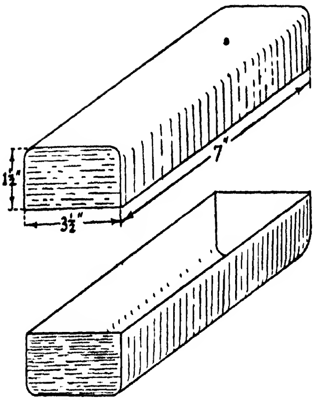


Fig. 72. A ventilator cover for a lantern. In the lower drawing it is shown upside down

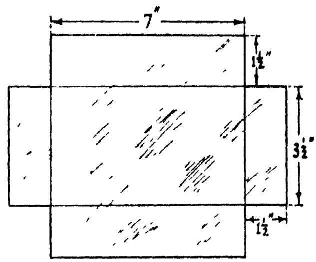


Fig. 73.
A sheet of metal cut and ready for bending for making a ventilator cover for a lantern

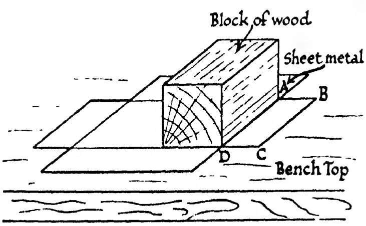


Fig. 74. Method of forming the sides of the ventilator cover

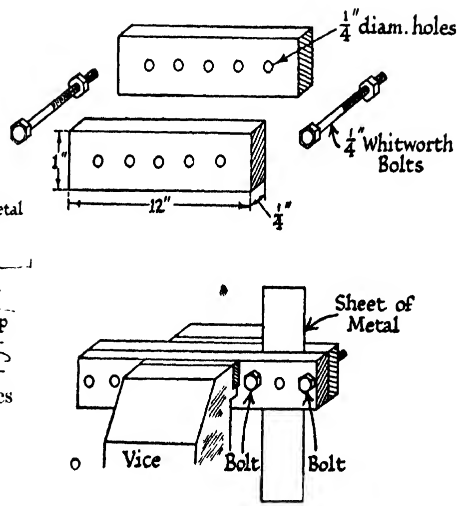


Fig. 75. Clamps for sheet metal work

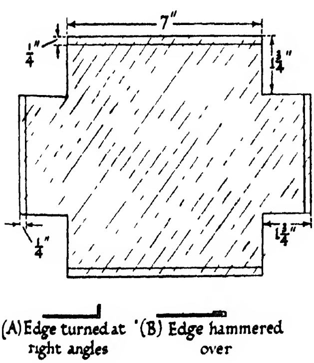


Fig. 76. Ventilator cover for a lantern. How to mark out tin plate to provide a turned-over edge

If a large opening be required it can be cut with the help of a pair of small snips after a hole has been drilled or cut with a cold chisel to enable the point of the snips to be inserted.

The cutting or drilling of the initial hole or holes is best done with the can slipped over a piece of wood of circular section. A broom stick gripped horizontally in a vice is suitable. The wood will provide a support and prevent the pressure of the cold chisel or drill from distorting the can. Centre punch before drilling or the point of the drill will slip about.

A narrow slot can be made by drilling two holes at a distance apart equal to the length of the slot and by cutting away the metal between them with a cold chisel, or better, by drilling a line of adjacent holes. If the metal in the neighbourhood of the slot tends to get bent during this process it can be straightened out with a few light blows from a hammer with the tin resting on the length of wood. A little cleaning up with a thin flat file will produce a neat slot.

80. To cut thick sheet metal.

Sheet metal that is too thick to cut with snips can be cut with the help of a cold chisel and hammer. During the cutting process the sheet should rest on an anvil, or failing this a flat stone or concrete floor.

If a small piece of metal only be required from a large sheet, it can be cut out with a hack-saw, but the shape of the hack-saw frame limits the depth of cut that can be taken with such a tool.

If the saw frame be held in position A fig. 78 rather than position B it is possible to obtain a greater depth of cut before the frame gets in the way and in any case the saw is easier to manipulate with less danger of the teeth being ripped out. If a circular disc is to be cut out, first scribe out the circle for the disc on the sheet of metal. Then with a hack-saw or cold chisel cut along AB and CB. This done, use a hack-saw, and cut off corner pieces as shown by dotted lines, fig. 79, and finally file the disc to exact shape. The metal should be held in a vice provided with jaw protectors to prevent the work being marked.

A slot or a large circular opening with a diameter greater than an available drill size can be cut in thick metal by drilling a series of holes and joining them together with the help of a small round file. A hand file can be used to complete the final shaping of a slot (Fig. 80) and a half round file should be used for a circle.

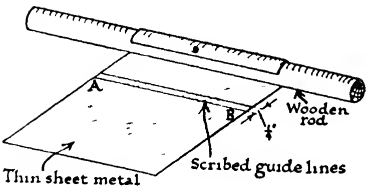


Fig. 77.
The construction of a tube

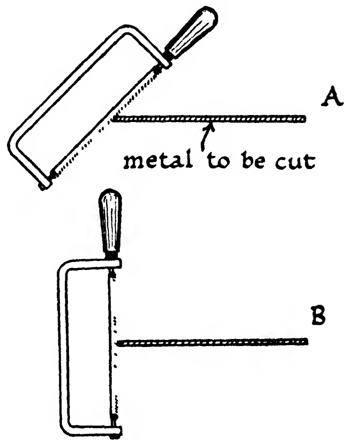


Fig. 78.
With a hack saw held in position A it is possible to obtain a greater depth of cut than in position B.

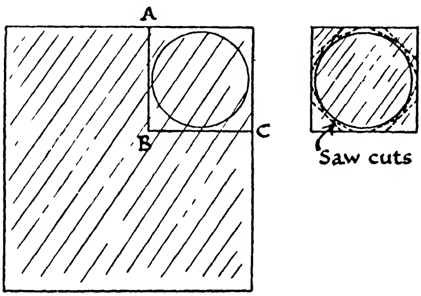


Fig. 79.
How to cut a circular disc from thick sheet metal

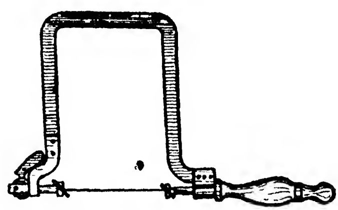


Fig. 81. Metal piercing saw

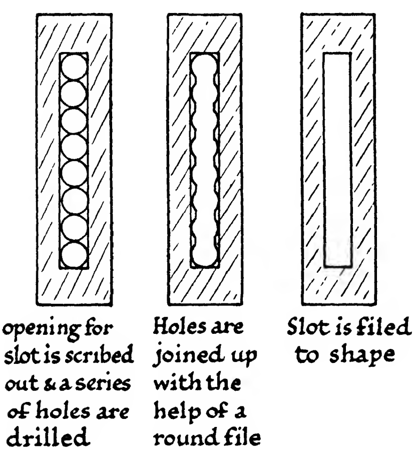


Fig. 80.
Cutting a slot in thick metal

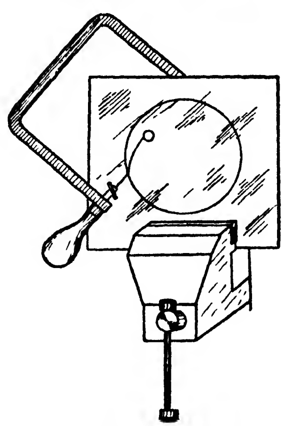


Fig. 82.
One method of using a metal piercing saw

Another method of making openings in either thick or thin sheet metal is to use a metal piercing saw (Fig. 81). Scribe out the opening, drill a $\frac{1}{16}''$ hole near the scribed mark in the part of the metal to be cut to waste. Fasten one end of a metal piercing saw in its frame, taking care that the teeth slope away from the handle, as in the case of fixing a hack-saw in a frame. Thread the free end of the saw through the drill hole made in the sheet of metal and there clamp it in the other end of the frame. Tension the saw blade with the adjustment provided, so that it gives an audible twang when plucked with the finger. Clamp the metal in a vice and saw out the opening, making a cut close to the scribed line. From time to time change the position of the metal in the vice so that the portion of the metal being cut is always close to the vice jaws and has plenty of support (Fig. 82).

81. Cutting metal tubing.

Metal tubing can be cut with a hack-saw. A fine blade with 32 teeth to the inch is better than a coarse one for cutting tubing. The teeth are less liable to catch and be ripped off.

If the tubing be thin, care must be taken, when holding it in a vice, not to crush and flatten it. A 'Yankee' Machine Vice No. 990 has a loose plate with V grooves in it to place between the ordinary plane jaws when tubing or rod has to be held. This is a very satisfactory arrangement.

When a length of tube is cut off a slight burr is formed on the inside. This can be removed with a round file.

82. Drilling metal tubing.

Always centre punch before attempting to drill a hole in the side of a tube. If the tube has thin walls, centre punch, as in the case of a tin can with a support placed inside (Sec. 79).

If a large hole has to be made in the side of a tube of small radius the point of the drill may tend to slip, although a centre punch mark has been made. In such a case, start by drilling a very small hole to act as a guide.

83. Bending brass and copper tubing.

Brass and copper tubing of a diam. up to $\frac{3}{8}''$ can be very easily bent if it be first made red hot and plunged, while so heated, into cold water. This has the effect of rendering the metal very soft and pliable. Heating without sudden cooling is usually sufficient.

If a long copper tube spiral has to be made the straight length

can be heated to redness in stages by moving it slowly through a cluster of Bunsen flames or the flame of a blow lamp or Primus stove. When this has been done, clean the tube with glass or emery paper and wind it round a cylinder of wood or metal of the required inside diam. of the spiral.

84. To cut metal rod.

Metal rod, brass, copper, aluminium, iron or steel can be cut with a hack-saw. A saw with 22 teeth to the inch is a good average grade of hack-saw blade to use.

Hold the rod in a vice during the sawing process and cut close to the vice jaws where the metal has good support.

Any sharp edge or roughness left by the saw can be removed with a file or by holding the end of the rod against an emery wheel. Turn the rod round with the fingers of the left hand while the wheel is rotated with the right.

85. To bend metal rod.

The blacksmith's method of bending iron and steel rod is to make it red hot and to bend it while in this condition. Metal rod, brass, copper, aluminium, wrought iron and mild steel of a diam. up to $\frac{1}{4}''$ can be bent cold while held in a vice.

Some qualities of metal are better than others for this purpose.

To bend a piece of brass rod for the formation of a clamp (Fig. 116) hold an inch length of the rod in a vice and support the longer, projecting piece with the left hand. Apply hammer blows to the rod about 2 inches away from the vice jaws and at the same time pull on the projecting piece (Fig. 83).

If hammer blows are directed too close to the vice jaws, a very sharp bend will be made and the metal of the rod may crack on the outside of the bend (Fig. 84).

The longer the projecting piece the greater is the amount of hand leverage obtainable.

If it is found that a sample of brass rod tends to crack under this treatment, although care be taken to avoid a sharp bend, make the rod red hot about the region where the bend is to be joined and soften it before bending by plunging it while still red hot into cold water.

86. To bend strip metal.

Strip metal is easily bent cold by a process akin to that described for rod (Sec. **85**). If brass or copper strip is being bent the serrated jaws of the vice should be covered with clamps.

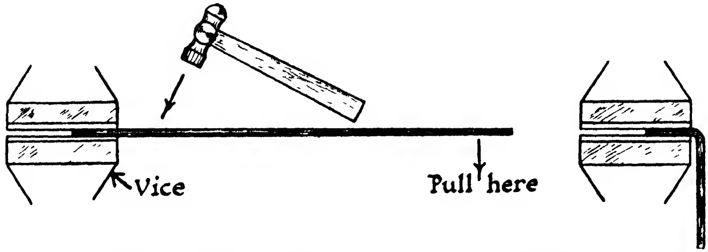


Fig. 83. Method of bending a rod to make a clamp

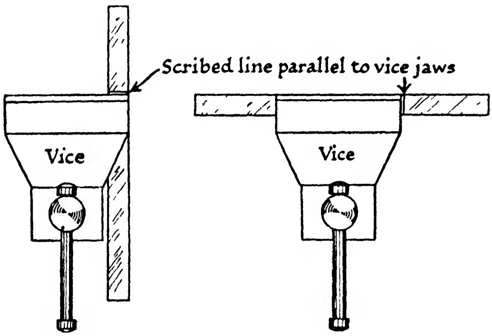


Fig. 85. Methods of clamping strip metal in a vice preparatory to bending

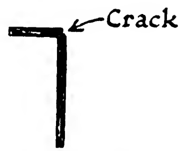


Fig. 84. Effect of too sharp a bend

Before effecting a bend, scribe a line across the strip with a steel square to serve as a guide line when clamping the strip in the vice. If the strip be not clamped at right angles to the surface of the vice jaws an imperfect bend will result (Fig. 85).

Strip mild steel and wrought iron up to $\frac{1}{4}''$ thick can be bent cold if a long projecting piece be left for hand leverage while the hammer blows are being applied.

87. To cut angle, square and channel iron and brass.

If metal of one of these sections has to be cut it should be scribed as shown in fig. 86 to avoid inaccuracy in sawing off and filing.

It is best to start sawing at a corner, fig. 87, about $\frac{1}{16}''$ away from the scribed line and to complete to exact length by filing. It is easier to start on a corner, rather than on a flat face. On a face the saw may slip about and the resultant cut may be made inaccurately. Once the cut has been started the saw can be gradually brought into a horizontal working position. In the case of angle and channel sections, it is best, once a side has been cut through, to turn the work in the vice and complete the cutting of

the second and third side with the scribed line facing upwards. This enables the worker to keep an eye on the line and to avoid cutting at a skew; there is also less danger of the saw teeth being ripped out by catching on a narrow edge.

88. Countersinking screw holes in metal work. (Fig. 88.)

When countersunk head screws or bolts are used to attach metal to wood or one piece of metal to another it is necessary to countersink the drill hole.

The preparation of a strip of metal for fitting to a wooden base board will serve as an example.

Measure out and mark the position of the screw holes. Centre punch and drill with a drill bit having a diameter equal to or very slightly larger than the upper part of the screw.

Now fit a brace, hand drill or bench drill with an 82° countersink bit and drill out the hole until the head of the wood screw will just fit flush with the surface of the metal strip.

To determine when enough metal has been removed it is necessary to raise the countersunk bit, lift up the metal strip, and test for depth by fitting a screw into the hole.

If rough work only is being done this rather laborious testing can be dispensed with, but in any case the countersinking must be continued until the top of the screw can sink flush with or just below the surface. A countersunk head screw or bolt with its head projecting above the surface is very unsightly and an indication of bad workmanship.

An ordinary carpenter's rose bit, having a brace bit shank, can be held in a carpenter's brace and used for countersinking metal, but a proper countersink bit made for metal working cuts more readily.

89. To make holes larger. (Fig. 89.)

A very common need is that of making a hole slightly larger. Sometimes a large enough drill is not available for making the initial hole, a given wood or other screw just will not fit into it. Occasionally a rod has to be fitted as accurately as possible into a hole or the opening in a washer slightly enlarged. The process of enlarging a hole, other than using a larger drill, can be carried out in various ways.

(1) *By the use of a Lancashire broach.*

Another name for this tool is a reamer; but as a rule small size reamers are known as broaches. It is convenient to have a small set of broaches, each tool mounted in a handle. To enlarge a hole the tool is pushed into it and turned round.

The cutting edges of the tool remove thin shavings. If one broach does not enlarge the hole sufficiently a larger one of the set should be used.

When a hole is being enlarged in strip metal to as accurate a fit as possible it is a good thing to use the tool first from one end of the hole and then from the other and so avoid the production of a tapered hole.

(2) *By the use of the tang end of a file.*

A rough and ready method of enlarging a hole is to clamp a file in a vice with its tang end pointing upwards. The metal with the hole in it can be slipped over the tang, pressed down and turned round and round, or alternatively the work can be clamped and the file held in the hand and turned.

(3) *By filing.*

A hole $\frac{1}{8}''$ or more in diameter can be made larger by filing with a round file. When this method is adopted care must be taken to file as evenly as possible all round or the hole will get out of shape.

90. The use of steel needles.

Portions of steel needles are sometimes required in the construction of apparatus. The points to form pivots and straight lengths to use as small axles.

Needles can be snapped in half by clamping the required portion in a vice and giving the projecting, unwanted part a sharp blow with a hammer.

It is best to use vice clamps of tin plate, if the needles be clamped directly between the serrated surfaces of the jaws it may not snap just where required. The steel of a needle is too hard to file, but it can be ground down on a carborundum stone or emery wheel.

91. To sharpen cold chisels, scribers and centre punches.

After some use these tools become blunted. They can be sharpened by rubbing on a flat carborundum grinding stone, using thin engine oil as lubricant.

An easier and very rapid method is to use a carborundum or emery wheel.

The wheel is used without lubricant and care must be taken not to overheat and destroy the temper of the steel as the result of heat generated by friction.

Apply the tool to the rotating wheel and every few seconds remove the tool and quickly dip it in water to cool the tip.

Scribers and centre punches should be rotated during the grinding process.

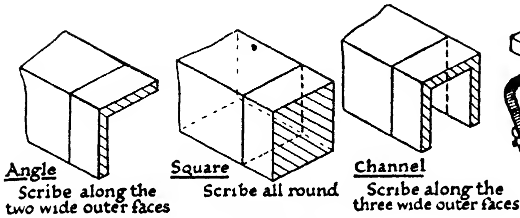


Fig. 86.
Marking out metal before sawing off

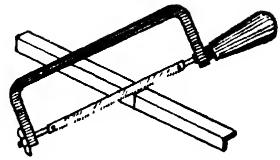


Fig. 87. How to saw a metal section. Start cut on the edge about $\frac{1}{16}$". away from the scribed line

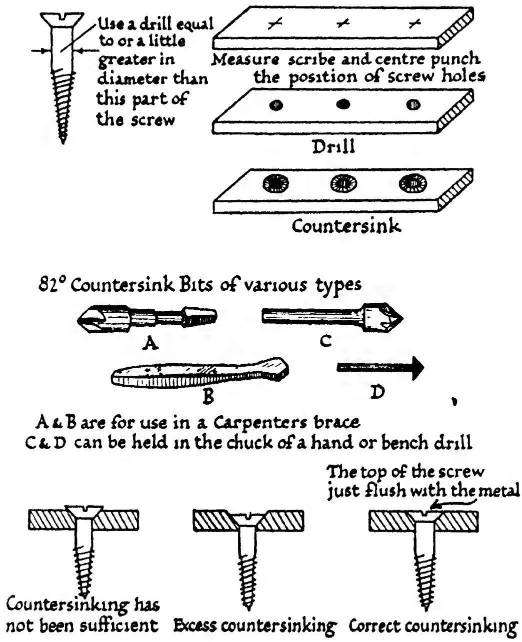


Fig. 88.
Countersinking screw holes in metal work

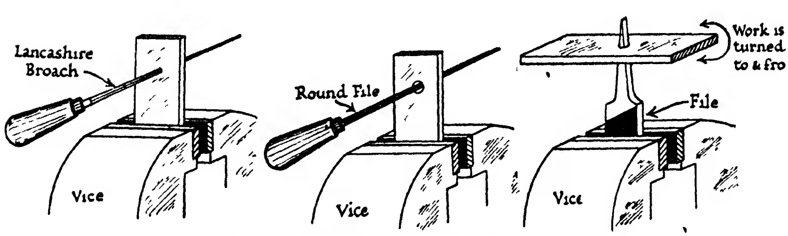


Fig. 89. Three methods of enlarging holes

CHAPTER V

SCREW CUTTING

92. Stocks and dies.

THE difference between British Association and Whitworth threads is explained in Chapter III.

An external or male thread such as that on a rod, or bolt can be cut by means of a die. A typical die is illustrated (Fig. 90). On the inside are a number of cutting edges of very hard steel, so formed that when the die is rotated on a rod of the correct diameter a screw thread can be cut on the latter.

A separate die is used for each size and type of thread.

The size is usually stamped on the surface of the die, $\frac{3}{8}$ W. or $\frac{3}{8}$ Whit. indicating that the die is constructed to cut a Whitworth thread on a piece of circular section metal of $\frac{3}{8}''$ diameter. A die to cut a British Association thread is stamped with the gauge number and the letters B.A.

The die is held by a tool called a stock (Fig. 91), that enables it to be rotated.

On the side of the stock is a set screw. When the die is fitted into the stock care must be taken that it is inserted the right way up or the end of the set screw will not fit into the cup shaped impression on the side of the die and serve the function of preventing the die from rotating.

Three methods are commonly in use for the adjustment of the cutting edges of the die.

Type 1. The die is made in two halves fitted into a stock with an adjustable handle.
By screwing up the handle the halves of the die can be brought nearer together (Fig. 92).

Type 2. The die has a radial cut made in it. A small grub screw can be screwed in or out, thus enlarging or diminishing the opening between the cutting edges (Fig. 93).

Type 3. The die is made in two halves, but fitted with a collar (Fig. 90) provided with an adjusting screw for altering the distance between the cutters.

Of the three methods, types 2 and 3 are more satisfactory than 1, since once the die has been adjusted for normal cutting it remains set for future use.

The 'Little Giant' series of dies can be purchased with collets (Fig. 90).

A collet is a guide below the cutting edges that prevents a 'drunken' thread being formed (see Sec. **94**).

93. To cut a Whitworth thread on a rod.

First measure the diameter of the rod with a pair of callipers and make certain that the equipment of dies includes one of the correct diameter. If the rod has a diameter of $\frac{1}{4}''$ the correct die to use is the one marked $\frac{1}{4}$ Whit.

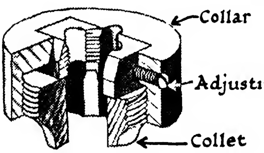


Fig. 90. A die of 'Little Giant' type shown in section. Type 3

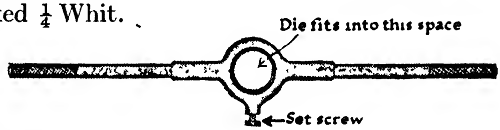


Fig. 91. A stock for holding a die of the 'Little Giant' type

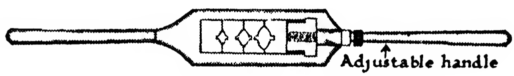


Fig. 92. A stock containing three dies each of the divided type. Type 1

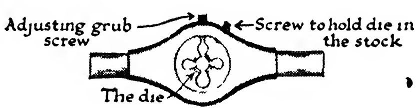


Fig. 93. A die with radial cut, grub screw adjustment fitted into a stock. Type 2

Place the rod in a vice and file the end as shown (Fig. 94). A coarse file can be used for this work. During filing keep the end close to the jaws or the rod may be bent under the action of the file.

Another method of shaping the end of the rod is to grind it down on an emery wheel. While grinding is going on the rod should be slowly rotated.

Clamp the rod vertically in a vice with the tapered end projecting about 2″ above the jaws. Having fixed the die in a stock, taking care that the set screw is holding, slip it over the tapered end of the rod. Grasp the arms of the stock and turn it slowly while pressing downwards at the same time. Keep the arms at right angles to the rod (see Sec. **94**). If sufficient taper has been given to the rod the die will soon begin to cut and form a thread. If it turns round and round without cutting, the cause may be due to one of two things.

(1) The rod may not be tapered enough, and requires further filing or grinding.
(2) The adjustment of the cutting edges of the die may be incorrect and may require separating.

If a thread is being formed on an iron or steel rod always use oil to lubricate the cutting edges of the die. Keep an oil-can containing motor-car engine oil close to the vice and every now and again drop oil into the die.

The use of oil is not necessary when cutting a thread on a brass or copper rod although, in this case, a better thread will be formed if oil be used.

After every few turns of the stock give it a half turn back again. This enables shavings to drop out of the die and prevents it from getting blocked.

As the thread is cut the bottom of the die will approach the top of the vice; if the rod has to be threaded a long way down it will be necessary to slacken the vice and raise the rod. Do not attempt to go on turning with the die touching the vice or injury may be done to the die or to the thread on the rod.

When sufficient length of rod has been threaded turn the stock anti-clockwise to remove the die. It often saves time to give the stock a good spin to unscrew the die, if a thin rod has been threaded more care should be used or the rod may be bent.

With some dies it is a little difficult to know just how far down the thread on the rod has been cut and it is necessary to turn the die backwards and inspect the rod from time to time.

Do not cut more thread on the rod than is necessary for the purpose in hand. A rod threaded for an unnecessary length involves waste of time, is unsightly and may cause undue weakening.

Once a thread has been cut on a rod it can be fitted with a nut of appropriate size. A $\frac{1}{4}''$ Whitworth nut on a $\frac{1}{4}''$ Whitworth threaded rod and so on.

Before attempting to fit a nut wipe the screwed end of the rod free of oil and metal shavings.

An old tooth-brush is useful for cleaning out the latter. If shavings are left in the thread of the rod, the nut may tend to bind.

When a rod is being threaded it will sometimes tend to slip round between the jaws of the vice, this is specially liable to happen if an iron or steel rod over $\frac{1}{4}''$ diam. is being threaded and clamped meantime between jaw protectors.

Sometimes a little extra tightening of the vice will stop the

trouble, but it may be necessary to clamp the work between the serrated jaws and dispense with protectors. If this be done the rod is liable to be marked, but in the majority of cases the marking is not serious and can usually be removed when screw cutting is finished, by the judicious use of a file and emery paper. If it is important that the rod should be free from all marks and as true as possible, then use jaw protectors and carry out the screw cutting process in two or three stages, each time adjusting the cutting edges of the die in towards normal position and take small cuts at each screwing down process, instead of attempting to cut a full thread in one stage.

94. Drunken threads.

If the stock be not held at right angles to the rod during the first stage of the cutting process the die will cut a thread at such a

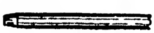


Fig. 94. Rod tapered ready for screw cutting

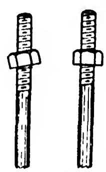


Fig. 95. Fig. 96. Rod with a drunken thread, and rod with correct thread

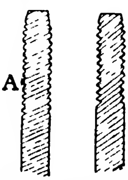


Fig. 97. Fig. 98. Rods with thread A incompletely, and B completely formed

slope that a nut when subsequently fitted on the rod will look like fig. 95 instead of fig. 96. A thread of this description is said to be drunken.

95. To cut a thread on thick rod.

If a good fitting thread has to be cut on $\frac{3}{8}''$ or $\frac{1}{2}''$ iron or mild steel rod it is best to do it in stages.

Taper the end as already described and start with the die so adjusted that the cutting edges are fairly wide apart.

Take a small cut, partly forming the thread to the required distance. It will look like fig. 97. Unscrew the die from the rod, adjust the cutting edges to a smaller opening and repeat the process of screw threading the rod. On the second time down the full thread can be cut and should look like fig. 98. Care must be taken not to adjust the cutting edges of the die in too far or more metal may be removed from the rod than is necessary to form the thread completely. For rough work a thread on a $\frac{3}{8}''$ or $\frac{1}{2}''$ rod can be cut in a single operation using plenty of oil and frequently turning the die back to clear the shavings.

96. To obtain a tight or a loose fit of a nut on a rod.

Sometimes a nut on a rod must be loose enough to be turned with the fingers, or possibly it must be so tight that vibration will not shake it loose, and it can only be turned with a spanner. The required conditions can be achieved by the adjustment of the die before the cutting process.

Start by adjusting the cutting edges fairly wide apart, then cut a thread on the rod. It is possible that the opening in the die has been made so large that the first screwing process will produce a thread on the rod with flattened tops owing to insufficient depth of cut (Fig. 97).

Unscrew the die from the rod and adjust the cutting edges to

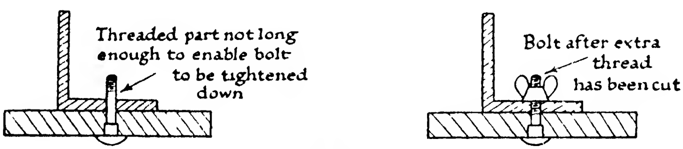


Fig. 99.

bring them in towards each other to a small extent. Again cut a thread on the rod with the die.

This second cut will probably produce a fully formed thread that will take a nut that can be turned easily with a spanner, but is too tight to turn with the fingers. This is the normal setting for the die and a good condition of adjustment to leave it in when it is put away for future use.

If the nut on the rod has to be finger-tight the halves of the die should be adjusted in towards each other a little beyond the normal setting.

97. To extend the threaded portion of a bolt.

It frequently happens that the threaded portion of a bolt is not long enough and when the bolt is passed through holes in two pieces of material for the purpose of holding them together the unthreaded part extends too far (Fig. 99).

This difficulty is easily overcome.

Clamp the bolt vertically in a vice with its head between the vice jaws, select a die cutting a thread of the same size and type as that on the bolt. Screw the die on to the bolt and cut additional thread to the required distance down. Use plenty of oil if the bolt be made of iron or steel.

98. To convert a bolt into a set screw.

A set screw is threaded the whole of its length; a bolt part of the way only (Figs. 31 and 30).

Sometimes a bolt has to be converted into a set screw. This can be done by cutting a longer thread on the bolt. After a time the bottom of the die comes up against the head of the bolt; this occurs before the die has cut a thread on the whole length. To overcome the difficulty, after cutting a thread in the ordinary way as far as possible, unscrew the die from the bolt and turn the whole tool, stock and die combined upside down. Again screw on the die and finish the final cutting of the thread with the die upside down (Fig. 100).

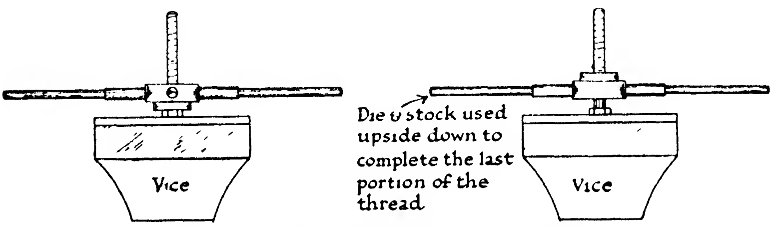


Fig. 100. Changing a bolt into a set screw

99. To construct a bolt from a length of rod, and a nut.

Thread one end of a rod to a distance a little greater than the width of a nut of corresponding size. Grip the rod in a vice and fit on the nut. Use a spanner and tighten the nut up as firmly as possible against the un-threaded part. Now cut across AB, fig. 101, with a hack-saw and finish off smoothly with a flat file.

Another method is to cut the rod with a hack-saw about $\frac{1}{8}''$ away from the nut and to hammer over and dome the projecting portion with the rounded end of a ball pane hammer (Fig. 102). This prevents the nut from untwisting and makes it very secure. During the hammering process it is best to grip the rod in a vice as shown in fig. 104, and not as in fig. 103. The former method prevents force being applied to the screw thread inside the nut, a possibility, should the grip of the vice not be quite secure.

This part of the work being completed the rod can be cut to the length of the bolt required and threaded to the necessary distance in the ordinary way.

This method of making a bolt is particularly useful when an extra long one is required.

100. To cut a British Association thread on a rod.

The instructions already given for the cutting of a Whitworth thread apply with equal force to the cutting of a British Association thread.

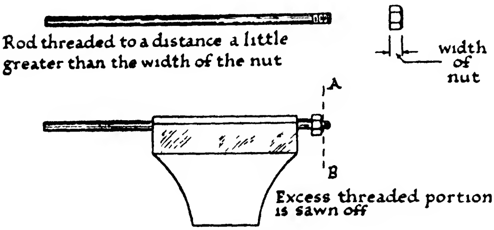


Fig. 101

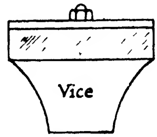


Fig. 103.
Incorrect position

Fig. 102. Constructing a bolt from a length of rod and a nut

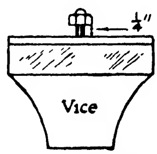


Fig. 104.
Correct position for rivetting

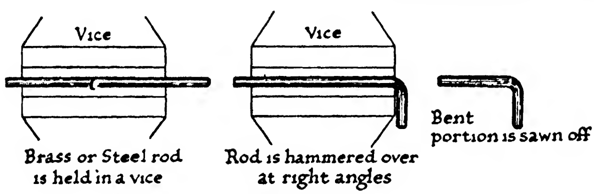


Fig. 105.

Since the size of a B.A. thread is not, as with the Whitworth thread indicated by a diameter measured in inches, but by gauge numbers, it is necessary to know the B.A. gauge number corresponding with a given diameter of rod before the correct die to use can be selected.

The following table gives this information.

Gauge No. of B.A. die.	Diam. of rod suitable for use with die.
0	$\frac{1}{4}''$ bare
1	$\frac{7}{32}''$,,
2	$\frac{3}{16}''$ full
3	$\frac{5}{32}''$,, (Meccano)
4	$\frac{5}{32}''$ bare
5	$\frac{1}{8}''$ full
6	$\frac{3}{32}''$,,

If a reference table be not available it is possible by holding a tap and a piece of rod up to the light and viewing them by a method akin to that indicated under Sec. **104** to select a tap having an overall diameter exactly the same or very nearly the same as that of the rod.

Suppose a No. 3 B.A. tap is found by this method to have the same overall diameter as the rod then the correct die to use for cutting a B.A. thread as the rod would be a No. 3 die.

This method is subject to error, especially when used for small size rods, and should not be applied when a reference list is available.

The word 'bare' in the list indicates that the rod is just large enough to take a B.A. thread of the given gauge number and the word 'full' that it is a shade too large theoretically for the given gauge, but can be used in practice. A Meccano axle will take a No. 3, B.A. thread and an ordinary bicycle spoke of No. 15, S.W.G. (·073″ diam.), will take a No. 9, B.A. thread.

101. The use of carriage bolts.

Fig. 99 illustrates a carriage bolt. These are made of steel and can be obtained from any ironmonger. They can be driven into a piece of wood; the square portion prevents them from turning when a nut is screwed on the threaded part. Fig. 99 also shows the application of a carriage bolt to attach an L shaped strip of metal to a baseboard.

To fit a carriage bolt first drill a hole in the wood equal in diam. to the diam. of the bolt. For instance, for a $\frac{1}{4}''$ Whit. carriage bolt use a $\frac{1}{4}''$ drill or twist bit. Drive the bolt into the wood with a hammer. Before this be done, make certain that the bolt has sufficient length of screw thread on it; if not put on extra thread with a die as described in sec. **97**.

102. The construction of clamping screws (Fig. 110).

These are made from round brass or steel rod.

Grip a length of rod in the vice with an inch or so projecting beyond the jaws. Now hammer this projecting piece over at right angles to the remainder. Avoid too sharp a bend or the metal may crack. Saw off the bent portion and cut a thread on one of the arms (Fig. 105).

If a thread be required on the whole length of one arm it will be necessary, when cutting the lower part, to remove the die and use the latter upside down (see Sec. **98**). It is best to do the bending of the metal rod before cutting the thread to avoid possible injury to the thread from hammer blows or the vice jaws.

103. To cut internal threads.

An internal thread is sometimes known as a female thread. An example of an internal thread is the thread inside a nut. Nuts made by machinery are so cheap that it is seldom worth taking the trouble to make them by hand, but it is often necessary, in the construction of apparatus, to cut internal threads in strip metal.

An internal thread is cut with a tool known as a tap (Fig. 106). After a hole of suitable size has been drilled out, the tap, held in a tap wrench (Fig. 107), is placed in the hole and turned round with

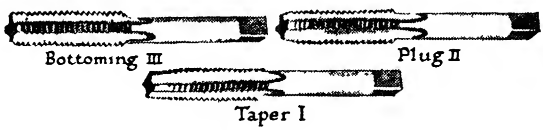


Fig. 106. Taps

the application of gentle pressure. The tap is made of hard steel and is so shaped that it can cut its way through the metal and form a thread at the same time.

Both taper-taps and plug-taps have the lower portion ground away, the taper one more than the plug. Both these tools cut gradually into the metal and do not make a complete thread until they have gone in some way.

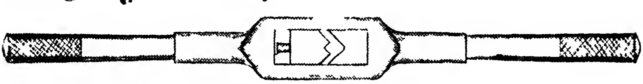


Fig. 107. A tap wrench

A full set of taps includes a taper, a plug and a bottoming one for each size or gauge number of thread.

Some confusion exists with regard to the names given to those tools by dealers and manufacturers.

The following are in common usage by London and Sheffield firms:

I.	II.	III (Fig. 106).
Taper	Plug	Bottoming
Taper	Second	Bottoming
Taper	Second	Plug

When only one tap per size of Whitworth or B.A. thread be purchased it is best to obtain a taper tap.

This is a generally useful form of tap, is very easy to use and will meet most of the requirements of a laboratory workshop.

A bottoming tap is seldom required and can be dispensed with See (Sec. **104**).

104. To cut an internal Whitworth thread.

The process of cutting an internal thread is known as tapping. Suppose a $\frac{1}{4}''$ Whitworth thread is to be cut in a strip of brass or mild steel about $\frac{3}{16}''$ thick.

First mark and then centre punch the position of the hole for the screw thread. This done, a drill has to be selected. A little consideration will make it evident that a hole smaller than a $\frac{1}{4}''$ in diam. must be drilled. If the hole be drilled out to $\frac{1}{4}''$ no metal will be left for the tap to cut into and form a thread, since the overall measurement of the tap is $\frac{1}{4}''$.

Many tool catalogues and reference books on workshop processes give lists of so-called drill tapping sizes. These are the sizes of drill to use for any particular size or gauge of tap. For a $\frac{1}{4}''$ Whitworth tap the correct drill to use is $\frac{3}{16}''$.

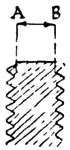


Fig. 108. Section of a Whitworth bolt male thread

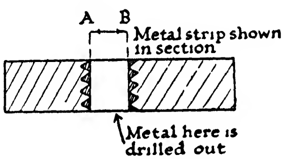
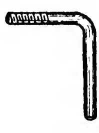


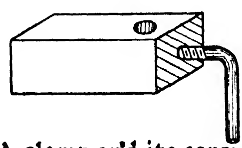
Fig. 109. The heavily shaded part is metal that has to be cut away by the tap used for forming a female thread

Fig. 108 represents a section of a portion of a Whitworth bolt, if a hole had to be drilled and tapped in a strip of metal for a bolt of this size it would be necessary to select a drill for making the hole having a diam. equal to the distance A B.

This would leave the metal shown heavily shaded in Fig. 109, to be cut away by the tap.



The finished Clamping Screw



A clamp and its screw

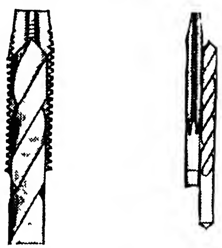
Fig 110. The construction of a clamping screw

The following table gives the correct tapping drill to use with each size of Whitworth tap. A copy should be made and exhibited in the workshop for reference.

Whitworth Screw Threads

Size of tap	Size of drill for tapping	Size of tap	Size of drill for tapping
$\frac{1}{8}''$	$\frac{3}{32}''$	$\frac{3}{8}''$	$\frac{19}{64}''$
$\frac{3}{16}''$	$\frac{9}{64}''$	$\frac{1}{2}''$	$\frac{13}{32}''$
$\frac{1}{4}''$	$\frac{3}{16}''$		

A reference table of tapping drill sizes is not always available; a rough and ready method of selecting the correct drill is to hold a tap and place a drill, that is thought to be of correct size, on the top of it. This done view them with one eye closed against a bright surface or white patch of sky.



If the drill be of correct size it should appear like this when held against the tap

Tap & Drill placed side by side.

Fig. 111.

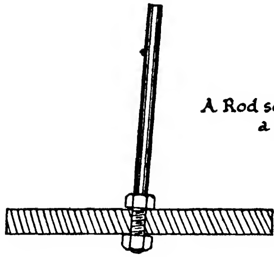
The drill should be of such a size that, viewed in this way, it is found to have a diameter as near as possible to the cross sectional distance between the bottom of the threads on the tap (Fig 111).

After drilling, grip the strip of metal in a vice and place the end of the tap in the hole. Now hold the wrench with both hands, and press and turn at the same time. If a hole of the correct diameter has been drilled the tap will soon begin to cut into the metal and start to form a thread. Take care to keep the tap at right angles to the work. It is advisable, once the tap has started to cut, to view it from two positions at right angles and so ascertain if there be any inaccuracy of position and correct it, if necessary, by slight sideways pressure on the tool in the appropriate direction.

If the initial hole has not been drilled at right angles to the surface or the tap be held incorrectly a screwed rod fitted into the hole may look like fig. 112, instead of fig. 113.

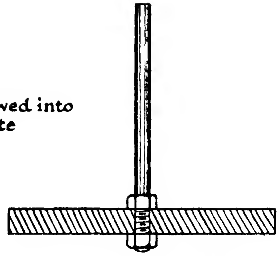
If iron or steel is being tapped keep the hole well lubricated with engine oil. Brass and copper can be tapped without oil, but it is wise to use oil in every case. After every half turn of the tap forwards give it a slight turn backwards to help in the process of clearing out shavings. If the tap shows the slightest tendency to twist with the cutting portion remaining fixed, great care must be taken in screwing it forwards, and a full half turn back should be given very frequently.

Beginners are liable to force and so break small size taps. Taps



The rod is out of the true due to an incorrectly drilled or threaded hole in the plate

Fig. 112.



The rod should be at right angles to the plate

Fig. 113.

are made of hard, but rather brittle steel and it is advisable to keep a supply of the small size taps, $\frac{1}{8}''$ and $\frac{3}{16}''$ Whit. in the store, to replace breakages. They are more liable to be broken when used to cut threads in iron and steel than in brass or copper. If a taper tap is being used, work it through the hole as shown in fig. 114, until the upper cutting portion comes flush with the surface of the metal being threaded. Remove the tap by turning the wrench backwards.

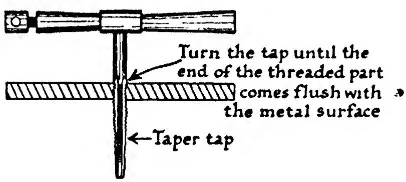


Fig. 114.

A plug tap begins to cut a full thread sooner than a taper one; this makes it more difficult to start cutting with a plug tap, especially in iron or steel. Once a thread has been started with a plug tap a bottoming tap can be used to cut a full thread to the bottom of a blind hole. A hole of this type is shown in fig. 115.

Hole drilled out ready to receive a thread

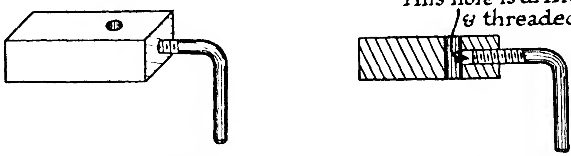
A Thread cut in a blind hole with the help of a bottoming tap

Fig. 115.

105. How to avoid the threading of blind holes.

The threading of blind holes can be avoided by the judicious

design of apparatus; but a rather similar practical difficulty arises in the construction of a clamp (Fig. 116).



A clamp and screw

Clamp and screw shown in section

Fig. 116.

A hole for the clamping screw has to be drilled and threaded and as shown in fig. 117, it is not sufficiently deep to allow a taper tap to enter far enough to cut a full thread.

The difficulty can be overcome by drilling the hole for the clamping screw to a greater depth than is necessary for the clamping screw to act as such, but deep enough to enable a taper or plug tap to cut a full thread in the portion where the screw has to work in and out (Fig. 118).

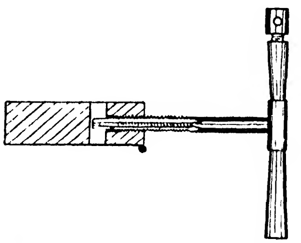


Fig. 117. The hole is not deep enough to allow the tap to cut a full thread

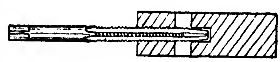


Fig. 118. How to drill the clamping screw hole to allow the tap to enter and cut a full thread

106. To cut an internal B.A. thread.

The process of cutting an internal B.A. thread is exactly similar to the process of cutting an internal Whitworth thread as described in Sec. **104**.

The size of a tapping drill to use in connection with any particular B.A. tap can be obtained from the following table. This table, like the one given for Whitworth taps, should be copied out and exhibited for reference in the workshop. If a reference table be not available a tapping drill can be selected by the inspection method described in Sec. **104**, but it is much better to make quite certain of selecting the correct drill by reference to a table.

The inconvenience of continually referring to a table for Whit.

or B.A. taps can be avoided by making a drill stand out of a small block of mild steel or brass (Fig. 119), and fitting it with drills of tapping sizes corresponding to the taps available.

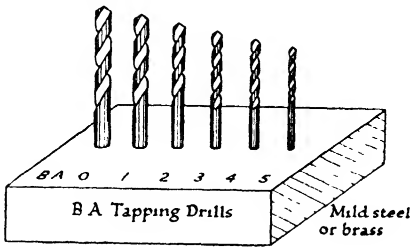


Fig. 119. A home-made stand and gauge for tapping drills

Each hole should be marked with the size or gauge number of the tap that the drill in that hole is to be used with.

The marking can be done by means of centre punch dots.

B.A. gauge No.	Size of drill for tapping	B.A. gauge No.	Size of drill for tapping
0	$\frac{3}{16}''$	4	$\frac{7}{64}''$
1	$\frac{11}{64}''$	5	$\frac{7}{64}''$
2	$\frac{5}{32}''$	6	$\frac{3}{32}''$
3	$\frac{9}{64}''$		

Drills can be bought in mm. sizes and in sizes measured according to a drill gauge number or letter. Many reference tables of B.A. gauge numbers and tapping drills give the drill sizes in these measurements. Since the list of tools given in Chapter II specifies drill sizes in fractions of an inch, the table given above indicates the drill in a $\frac{1}{64}''$ series that is the nearest size suitable for the purpose of tapping.

107. The use of a backing nut.

Sometimes it is convenient to attach a rod to a metal plate, in the construction for instance, of a prism stand for an optical bench (Fig. 120).

If a metal plate $\frac{3}{32}''$ to $\frac{1}{8}''$ thick be drilled and then threaded with a $\frac{1}{4}''$ Whitworth tap, only a small length of thread can be cut in the thin metal and a rod screwed into it will have little support. In such a case it is best to thread the rod for about $\frac{1}{2}''$ and to fit it with a nut. The rod is screwed into position and the nut then tightened up against the plate to form a backing nut. In this

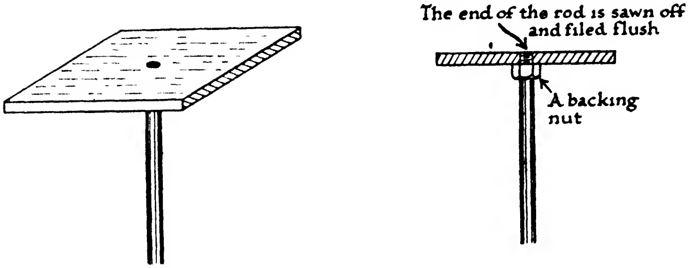


Fig. 120. A prism stand for an optical bench

way it is possible to obtain a firm attachment of a rod to a thin metal plate. If necessary the attachment can be given extra strength by running solder round the edge of the nut in contact with the plate. The end of the rod may project through the plate, if so, it should be filed down flush.

108. To repair an injured bolt or rod.

The thread on a rod or bolt may be injured by a hammer blow or by undue pressure in a vice. It can usually be put in order by treating it as a rod to be threaded and passing it through a die of the correct size. This will reform the thread.

109. Stripped and worn threads.

If an internal or external thread has been broken or worn away it is best to fit a new nut, bolt or length of rod as the case may be.

A temporary repair can sometimes be effected by winding a piece of cotton round the external thread and so providing extra grip with the internal thread. It is best to replace the injured portion or to drill out the old internal thread and cut a new larger thread with a tap.

110. How to deal with tight nuts.

Sometimes, when an attempt is made to fit a nut to a length of screwed rod or to a bolt it will be found very difficult to turn, even with a spanner. The tightness may be due to an injured thread on the rod, or to the use of a die with its cutting edges not adjusted to cut a full thread on the rod, but it is very likely due to the nut itself.

The trouble is particularly liable to arise if black forged nuts or pressed nuts are used instead of bright steel ones. The latter are more accurately made than either of the other two.

A tight nut can be quickly put in order by clamping it in a vice

and screwing a tap of appropriate size through it. If a taper tap be used and the nut is a thick one it may be necessary to remove the nut and screw the tap through it from the other side in order to cut the thread inside the nut to full size.

Old nuts are also liable to be tight, owing to damage or rusting of the thread. These may be put in order by the above method.

111. To cut a new thread in a nut or terminal top.

Old nuts and terminal tops can often be utilized and provide an emergency store.

It is possible that a terminal or nut with some particular thread is not available. A ¼″ Whit. nut may be required when the only nuts available are too small or B.A. gauge.

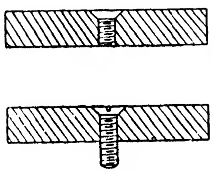


Fig. 121. The countersinking of a threaded hole

For example to convert a 3/16″ Whit. nut into a ¼″ Whit. nut. Drill out the old thread with a tapping size drill, for ¼″ Whitworth, then cut a new thread with a ¼″ Whitworth taper tap.

The milled edge nuts on old dry batteries should be kept. The B.A. thread can be drilled out if necessary and a 3/16″ Whit. thread cut in its place.

112. To countersink screw holes in strip metal.

If countersunk head screws are to be fitted into a metal strip or plate (Fig. 121), first mark, drill and thread the hole in the plate and do the countersinking last of all. Use an 82° countersink (see Sec. 88).

113. To cut an internal thread in wood.

A Whitworth thread can be cut in hard wood such as oak or beech in exactly the same way as in metal after a tapping drill hole has been made. If a rod has to be fitted into a base-board it can be done by one of the methods shown in fig. 122.

In A the base-board is fitted on the under surface with extra strips of wood. A hole with a diameter equal to that of the rod is drilled in the board.

In B a hole is cut in the under surface of the board to take the bottom nut and again a hole with a diameter equal to that of the rod is drilled in the board.

In C a screw thread is cut in the wood, the rod is screwed in and tightened up with a backing nut.

114. Brass thread and the repair and use of gas fittings.

Brass gas pipes and laboratory gas fittings are threaded with a special thread known as the Brass Thread. This thread is so designed that it has 26 threads to the inch in all diameters.

If an attempt be made to cut a Whitworth thread on a length of brass gas pipe it will be found that the die cuts so deeply into the

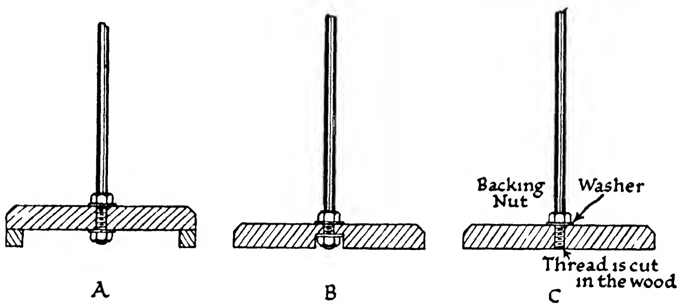


Fig. 122. Three methods of fitting a rod on to a baseboard

thin wall of the tube that the latter is crumpled and broken.

The Brass Thread is akin to the B.A. thread in being of shallow type.

Sets of stocks, dies, taps and wrenches for cutting a Brass Thread can be purchased, but many of the ordinary requirements of a laboratory workshop can be satisfied by the use of a simple tool known as a Combination Gas-Burner Tap (Fig. 123).

This comprises a $\frac{3}{8}''$ die for Brass Thread, one or two taps, a reamer and a screwdriver. The latter is not necessary, but completes the symmetry of the tool. It costs about 4 /6.

Economy of Purchase

If a set of Brass Thread dies and taps be ordered and a range of Whitworth 'Little Giant' dies and taps, items No. 1 and 2 in the tool list have already been bought, it is an economy to buy Brass Thread dies with collets of the same external diameter as the Whitworth dies so that one stock can be used for both sets. Useful sizes are $\frac{1}{4}''$, $\frac{3}{8}''$ and $\frac{1}{2}''$.

One plug tap per size will serve most purposes and can be held in the wrench used for Whitworth taps.

Brass tubing as used by gasfitters has fairly thick walls. The size of a brass gas pipe is specified by the outside diameter. $\frac{3}{8}''$ brass gas pipe should be purchased for ordinary work and will be found very convenient for making extensions to a gas or water supply. It is much better and more durable for the purpose than flexible gas or rubber tubing.

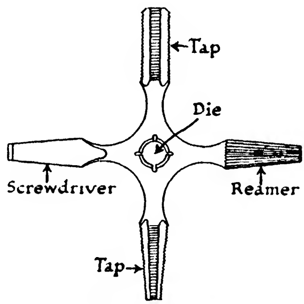


Fig. 123. A combination gas-burner tap

Ironmongers and the 6d. Stores stock a variety of small brass gas fittings that are often useful when making up apparatus (Fig. 124).

These enable straight lengths of pipe to be extended or carried round corners at right angles.

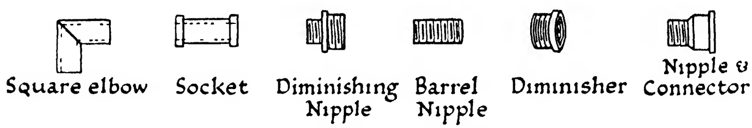


Fig. 124. A selection of useful gas fittings

115. To cut a thread on a $\frac{3}{8}''$ brass pipe.

Bevel the end of the pipe with a file and use the die in the manner described for Whit. and B.A. dies (Secs. **93** and **100**).

116. To cut an internal brass thread.

The tapping drill size for $\frac{3}{8}''$ Brass Thread in the nearest fractional inch size is $\frac{21}{64}''$.

If a special drill be bought the exact tapping size can be obtained in the decimal of an inch or letter gauge series of drills. The tapping drill size in this case being Q or ·332″.

If the metal being tapped be fairly thin a drilled hole can be

opened up by the reamer to be found in the Combination Tool to a size large enough for the insertion of the taper tap.

Brass tubing is easily bent into curves and spirals if it is first annealed.

117. To anneal brass tubing.

Make the tube red hot and immediately plunge it into cold water. This renders the brass very soft and easy to bend. Copper tubing can be softened in the same way.

118. To repair Bunsen burners.

The gas inlet tubes of Bunsen burners sometimes get lost or broken. A new side tube can be made from a length of $\frac{3}{8}''$ brass gas pipe. Cut a $\frac{3}{8}''$ gas thread on one end of a short length of pipe and screw it into the base of the burner. File off the sharp edge on the far end of the pipe, so that it will not damage a rubber tube connection.

119. To repair gas connections.

The gas tap connections for rubber tubing on lecture tables and benches sometimes snap off owing to corrosion or rough handling.

Before a new tap can be fitted, the old broken end left in the pipe must be extracted (Fig. 125).

Sometimes sufficient length of the broken stub end projects to enable it to be grasped with a pair of pliers and so unscrewed, or a screw-driver pressed into the opening may enable it to be turned and extracted.

The taper tap of the combination tool is also helpful and will often cut out the old end. If all these methods fail take a small drill and carefully drill two holes to a depth of $\frac{1}{8}''$ at opposite places in the fractured face of the broken end. This enables a screw-driver to be brought into effective action.

120. To make joints gas-tight.

If a joint in a connection be not gas-tight it should be unscrewed and the male thread of the connection should be painted with some thick paint or smeared with a mixture of white lead powder and boiled linseed oil. This can be prepared by placing some boiled oil in an old tin lid and dusting white lead into it to form a mixture of thick cream consistency. Keep the oil stirred while adding the powder. After treating the connection, screw it together again.

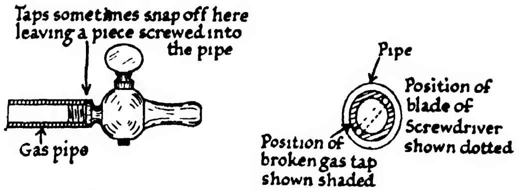


Fig. 125. The repair of gas connections

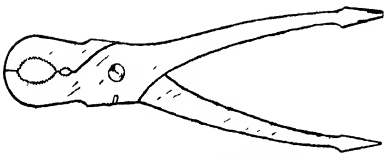


Fig. 126. Gas pliers

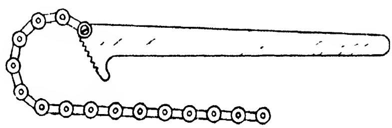
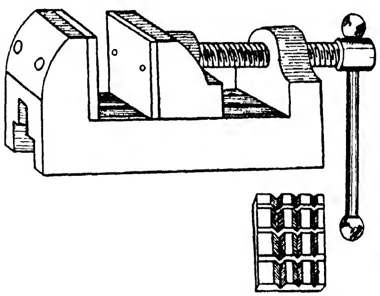


Fig. 127. A pipe-wrench
By courtesy of Perry & Co., Ltd.



This vice can be clamped in an ordinary parallel jaw bench vice or used on the base of a drilling machine

Fig. 128. A machine vice fitted with a V-face plate
By courtesy of North Bros. Mfg. Co.

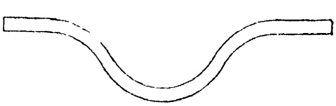


Fig. 129. Avoid downward loops like this when using composition pipe for gas connections

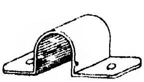


Fig. 130. A saddle used for attaching pipes to walls

121. Methods of holding pipes.

A useful tool for holding and turning a pipe is a pair of gas pliers (Fig. 126).

Another very useful tool is a Perry chain pipe wrench (Fig. 127), to be bought for 1 /– from the Halford Cycle Co., Ltd., Corporation Street, Birmingham. The latter can also be used to unfasten large nuts or to unscrew an obstinate tin lid of the screw top type.

Where brass tubing is being held in a vice for the purpose of screw threading, care must be taken not to crush it. If necessary, slip a piece of small diam. dowelling into the tube to give it support on the inside, or grip it with a V-face plate as supplied with a 'Yankee' machine vice (No. 990) (Fig. 128).

122. Composition ('Compo') pipe connections.

Plumbers often make gas connections with 'compo' pipe. This is manufactured from lead hardened by alloying with antimony or tin. It can be bought in long lengths, is very soft and can be bent just as required.

If gas connections are made with it take care to avoid any downward loops as shown in fig. 129, where liquid might collect as a result of condensation.

Both brass tubing and 'compo' pipe can be attached to walls or bench sides by means of saddles (Fig. 130).

Brass tube connections are easily soldered into 'compo' pipe (see Sec. **150**).

123. Screw threads for iron pipes. (Known in the Trade as 'wire barrel.')

Iron pipes are always specified according to the internal diameter; a so-called $\frac{1}{2}''$ iron pipe has an internal diameter of $\frac{1}{2}''$, but the external diameter is about $\frac{3}{4}''$ since the wall of the pipe is nearly $\frac{1}{8}''$ thick. It should be noted that the system of specification used for iron pipes differs from that used for brass and copper pipes. A $\frac{1}{2}''$ brass pipe is one with an external diam. of $\frac{1}{2}''$.

Iron pipes used for gas, water and steam supplies in a laboratory are threaded with the Iron Gas Thread, not the ordinary Whitworth, B.A. or Brass Thread, and special dies and taps have to be used.

If water supplies have to be extended or modified it is very convenient to have a die cutting $\frac{1}{2}''$ Iron Gas Thread. A 'Little Giant' type die for this size with a stock costs about £1.

All ironmongers keep a variety of fittings such as sockets, round elbows, square elbows, barrel nipples, back-nuts, tees, plugs, caps,

diminishing or reducing sockets and so on that only cost a few pence and enable the laboratory worker to carry out a variety of minor alterations and extensions to a gas or water supply using iron pipes (Fig. 131).

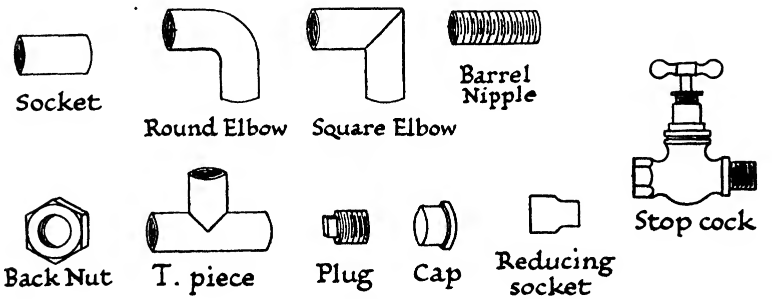


Fig. 131. Iron pipe fittings

Four examples are given of the use of such fittings to modify a water supply (Figs. 132–135).

In examples, figs. 133 and 134, the use of a die is not called for. In figs. 132 and 135 a die has to be used once in each case to cut a thread on the short length of pipe AB, so it would be scarcely worth while purchasing a die to do the screwing if this was the only work to be done, since the short length of pipe could be cut as required, and threaded by the ironmonger supplying the various fittings.

A standard length of pipe is 10′ with a male thread at each end.

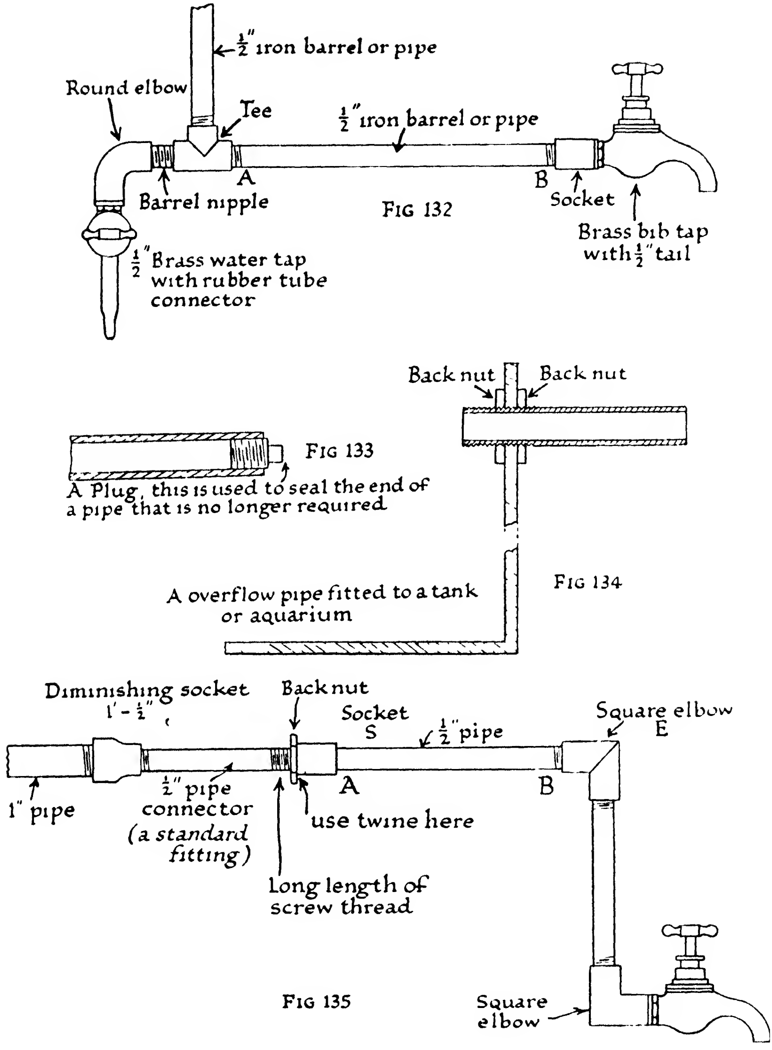
In the trade it is usually referred to as barrel and not as pipe.

If cut to a shorter length it leaves one end without a thread and the use of a die becomes necessary.

When making measurements for the total length of a pipe between fittings an addition in length to the pipe of about ½″ per fitting should be allowed for screwing in.

Before fittings are screwed together the male threads should be treated with a paste of a mixture of red lead, white lead and boiled linseed oil, or powdered graphite and boiled oil. To make certain of a water-tight fit a few strands of tow or threads from a hemp rope should be wound round the male thread and smeared with the paste before the joints are put together. The screwing on of a length of pipe or of fitting one into another can be carried out with the help of a good chain pipe wrench or a large 'Footprint' type wrench (Fig. 136). (12″ size approx. cost 3/6.)

Sometimes two wrenches are necessary; for simple work it is



Figs. 132–135

often possible to assemble many of the fittings on a bench and make use of a vice.

124. Use of back-nuts.

Pipes and fittings should be screwed together until the tight end parts of the threads make good engagement. Sometimes the exigence of space or length of pipe does not allow this to be done.

In example, Fig. 135, the diminishing socket and the square elbow E might already be fixed in position or possibly they have to be an exact distance apart. The use of a connecter and back-nut allows for the insertion and adjustment of a length of pipe between the diminishing socket and elbow.

One end of the connecter has a long length of screw thread on it and this allows the socket (S) to be screwed along it out of the way during the insertion of AB. When S is screwed back to engage tightly with AB it will be left on a loose part of the connecter.

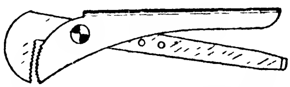


Fig. 136. A 'Footprint' type wrench

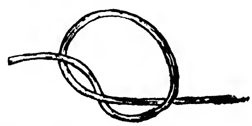


Fig. 137. A half knot used for tying a grummett

A tight joint is made by screwing up the back-nut.

Before screwing up a back-nut tie a piece of hemp twine round the pipe connecter. Use a half knot (Fig. 137). Smear the twine with jointing paste, then tighten up the nut. Plumbers call this 'tying a grummett.'

Before new water connections are made it is of course necessary to turn off the supply.

Pipes can be fixed to walls with pipe clips or hooks. A $\frac{1}{2}''$ pipe requires a $\frac{1}{2}''$ clip or hook. A die for cutting iron gas thread is used as described for cutting a thread on thick rod, Sec. **95**, but it is best to start with the die cutting edges fairly wide apart and work down to the full cut in two or possibly three stages.

This avoids the application of great force and expenditure of energy possibly with injury being done to the die. The pipe should be held in a strong vice to prevent it turning during the cutting process. Special vices are made for holding pipes, but an ordinary one can be used if the precaution be taken of cutting the full thread in gentle stages as described. Use plenty of oil.

The threads inside iron pipe fittings are sometimes imperfect or blocked with rust and paint.

When making a purchase it is advisable to test each fitting in turn by screwing in a length of straight pipe.

This precaution is not necessary if the tool equipment includes a $\frac{1}{2}''$ Iron Gas Thread Plug Tap. (Price approx. 2/9.)

A fitting with a tight or faulty thread can be quickly put in order by screwing this tap in and out. An ordinary spanner can be used to turn it round while the fitting is clamped in a vice.

CHAPTER VI

SOLDERING

125. Tools and materials.

SKILL in the art of soldering is indispensable to the metal worker, it is a process that is constantly required in apparatus construction and in general repair work.

If various precautions are taken the process is easily mastered and good work can be carried out from the start.

The tools required are a soldering iron and one or two files, and the chief materials, a supply of flux and a stick of tinman's solder.

For convenience in working a number of small accessory items are desirable and these will be described in due course.

The end part or bit of a soldering iron is made of copper; these tools are sold according to the weight of this copper portion.

A 1 lb. iron with a straight, pointed bit is a useful size and form for general work. The best flux to use is a solution of zinc chloride, a liquid akin to this, and stocked by all ironmongers, is sold under the trade name of Baker's Fluid.

Workmen refer to zinc chloride as 'killed spirit'; it can be prepared by first cutting some scraps of sheet zinc into conveninent portions with a pair of snips and placing them in a beaker or glazed earthenware pot. This done, add commercial hydrochloric acid to cover the zinc to a depth of an inch or so. Vigorous evolution of hydrogen takes place with formation of much acid spray. The latter has a corrosive action on tools, so place the beaker outside the workshop during the evolution of gas. Use an excess of zinc. After half an hour, when all action is over, filter and collect the clear solution.

Place some of the home-made solution or Baker's Fluid in a small pot; it is convenient to have another supply in an unspillable ink-pot.

A suitable pot is a strong glass or glazed earthenware one as used for the sale of ointments and potted meat.

During the process of soldering the heated bit is dipped into the solution in the pot and may hit against the bottom and crack a thin glass one. The depth of solution should be about $\frac{1}{2}''$.

The bit of the soldering iron has to be heated. If gas be

available this can be done by resting the iron on a three-legged stand with the bit projecting over a Bunsen flame (Fig. 138). A Primus stove, a blow-lamp or a clear wood or coal fire can all be used. A non-smoky source of heat is required.

The bit has to be heated to such a temperature that it will cause the solder used to melt and become almost as fluid as water. It should not be made red hot. When it is thought that the bit has reached a high enough temperature, remove it from the flame and hold it about 1″ away from the cheek. If distinct radiation be felt it is probably hot enough. Rest the stem of the iron on the edge of a vice, not on the bench where it will burn the wood and,

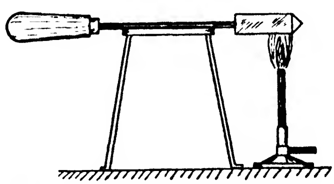


Fig. 138. Heating a soldering iron

without undue delay, quickly file the four faces of the point of the bit. An old 10″ second cut file is suitable. File and clean away scale and oxide to about $\frac{1}{4}$″ from the point of the bit.

The filing must be done very rapidly to prevent too much cooling. If an old iron that has got into a bad condition is being used it is a good thing to give it a preliminary filing and general cleaning up and re-shaping before it is heated.

Pick up the pot containing flux, hold it at arm's length, away from tools and other objects on the bench where spray may do damage, and as quickly as possible dip the point of the heated bit into and out of the liquid. If the bit has been heated sufficiently and has not cooled down too much during the filing process, a sharp sizzling sound will be made as it is dipped in.

Place a scrap piece of tin plate or the lid of a tin can on the work bench. If a lid be used it must be free from enamel.

The process of quickly dipping the heated bit into and out of the flux dissolves off the film of copper oxide and leaves clean metal exposed. Without delay, or a new film will form, press a clean side of the tip of the bit against a stick of solder and allow the molten drop to collect and form a globule on the piece of tin.

Turn the bit over and over and rub it up and down in the globule. If it has been properly filed, cleaned in flux and has not got too cold, a film of solder will attach itself to the cleaned surfaces.

This process is called 'tinning the bit.'

If the solder fails to attach itself, quickly dip the bit a second time in and out of the flux and try again. If again not successful, then file clean and dip a third time. The bit of a soldering iron should always be 'tinned' and brought into good condition before the commencement of soldering operations.

126. Soldering sheet and strip metal.

Tin-plate is the easiest of all metals to solder and anyone wishing to practise soldering will be well advised to try soldering together some strips of tin plate or the edges of a cocoa tin and lid to make it air tight. The tin, if air tight, can be used to demonstrate the pressure of the atmosphere.

As an example of procedure take the case of the soldering of the turned up sides of a rectangular tin box (Fig. 139). The soldering should be done on the inside.

First paint the surfaces to be soldered with flux. Use the clean supply from the unspillable ink-pot. A small penny brush, as supplied in a child's paint-box is suitable, but a better brush is one with the hairs set in a quill without any metal to corrode. Paint the edges on the inside only to a width of $\frac{1}{8}''$. The flux must be painted on where the solder is required.

The action of the flux is to dissolve away the film of oxide and yield a clean surface for the attachment of the solder.

It is absolutely essential to have clean surfaces for soldering. If the box had been made of brass, copper or zinc it would be necessary to make the surface to be soldered quite clean by scraping with an old knife, by filing, or by sand-papering as happens to be most suitable. Once a surface has been cleaned for soldering avoid fingering it and keep it free from all oil and grease. As a general rule, tin plate does not require any cleaning before treating with flux, but of course remove rust, gum, enamel, paper and such like if a tin can is being soldered.

While the work is being prepared the soldering iron should be heated. If it has not already been tinned this should be carried out and the bit again heated. When hot enough, and this can be tested by holding it close to the cheek, quickly wipe the bit with a piece of linen or cotton rag, do not use a woollen rag. The wiping will expose the clean tinned surface, and take away any lead oxide, rust or coal dust, that may be present.

Now dip the bit very quickly in and out of the flux in the pot. If the bit has been tinned, this dipping into flux will leave the end in such a condition that molten solder will adhere to it.

Solder can be applied to the work in various ways.

Press the end of the bit against the end of a stick of solder, when some will melt and stick to the tinned bit.

Apply the bit to the place to be soldered and slowly draw it along the joint. If enough solder has been gathered up it will run off the bit and into the joint. If more solder be required, collect it as before and apply it to the joint.

If necessary, smooth all lumps out by slowly drawing the hot bit from end to end of the joint.

Sometimes the only effect of trying to pick up solder in this way is to cause it to melt and drop on the floor. To avoid this the solder can be melted off the stick while its end is held close over the joint.

The best method of all, and one that avoids the application of not enough or too much solder, is to melt off small globules of solder about $\frac{1}{8}''$ diam. by holding the bit against a stick of solder, and by collecting the globules that are formed on a sheet of asbestos or Uralite placed just below.

The globules solidify in a few moments. By application of the hot bit to them they are melted and easily picked up, one by one, and applied to the work.

If too much time is spent in making the globules the bit will get so cold that it will cease to melt the solder properly, and will have to be re-heated. In any case, if much soldering has to be done, the bit must be constantly re-heated.

After picking up a globule, and when carrying it to the work, keep the soldering iron steady or the globule may drop off.

If more convenient, little prepared lumps of solder, formed by melting off from a stick, can be arranged on the joint to be soldered and re-melted in position by the hot bit.

Many beginners attempt to solder with a bit that has been insufficiently heated at the start, or has cooled down below the effective soldering temperature.

The bit must be hot enough to cause the solder to become completely fluid. It is quite useless to start, or attempt to continue soldering if the temperature of the bit is not high enough to bring about or maintain this condition.

When a bit has been re-heated always wipe it and dip quickly in and out of the flux pot before starting any more soldering. After several re-heats it may be necessary to tin the bit again, it is important to keep it in this condition for good work; the process only takes a few seconds and is time well spent.

If the bit be overheated and made red hot the tinning will soon

disappear and it will be necessary to repeat the tinning process more frequently.

When soldering an object, like a rectangular box, it is advisable to tilt the object so that gravity helps the flow of the molten solder in the right direction.

If much soldering has to be done it saves time to keep two irons going. One can be heating while the other is being used.

Drops of molten solder and objects that have been heated by application of a soldering iron may injure a good table top. A very satisfactory bench or table top cover for soldering on is formed by a sheet of Uralite measuring 12″ square or an asbestos roofing tile costing 3d.

If zinc chloride solution, or Baker's Fluid be used as a flux, take care to wipe or wash the soldered joint on completion of the work. Both substances are very hygroscopic and may produce corrosion if left on the metal.

The chief rules for successful soldering are:

(1) The parts of the work to be soldered must be clean and treated with flux.
(2) Use a tinned bit.
(3) Heat the bit to such a temperature that it makes the solder quite fluid and not pasty.
(4) Wipe the bit.
(5) Dip it quickly in and out of the flux before use.
(6) Do not continue to use a bit that is no longer at a high enough temperature.
(7) Avoid excess of solder.

The work of a beginner is usually characterised by a lumpy excess of solder. This is usually caused by an attempt to use a bit that has not been tinned, dipped into flux before use, or by an attempt to use it before it has been properly heated, or after it has cooled below the effective temperature.

In a good soldered joint the solder sinks into the surface of the metals to be joined and only a small amount is necessary to bring about a strong union of the parts if the work has been done properly.

Sheet brass, sheet copper and sheet zinc can all be soldered by the method described.

Large thick copper objects are sometimes difficult to solder owing to the good heat conducting property of copper. When a small soldering iron is used for such work it quickly cools down, has to be constantly re-heated and it is often difficult to get the solder to flow properly. In such a case it is best to use a soldering

iron with a large bit, one capable of retaining a good quantity of heat and if necessary impart some heat to the object to be soldered by the judicious application of a Bunsen or other clear flame.

127. To solder two pieces of strip brass together. (Fig. 140.)

This can serve as an example of various methods of soldering.

Method I. Direct application of solder by means of an iron.

A little difficulty here is to keep the two strips in correct position during the soldering process.

The position of the upper strip should be marked on the lower one by scribing a line on the latter. Clean the surfaces to be joined; this can be done with fine glass or emery paper.

Now paint over with a thin film of flux. In the case of the upper strip put flux on the under surface, on the lower vertical surfaces A and B, also on the other two vertical surfaces not shown in the diagram (Fig. 141). Similarly, treat the area on the lower strip that will be covered by the upper one, but make it about $\frac{1}{4}''$ larger all round.

It may be possible to hold the upper strip in position with the fingers during the soldering process, but if it is short it will get too hot to do this. One way of keeping it in place would be to hold it down with the end of some tool pressed on the bottom horizontal portion. For preference use something small and rather pointed, such as the tang end of a file, that will not conduct very much heat away.

Apply solder by one of the methods already described and take very great care not to let the upper strip move while the solder is going hard. During the solidification of solder, owing to its alloy nature, it goes through a stage of partial solidification before it sets hard throughout.

If the surfaces to be joined are subject to movement, during this critical condition of the solder, the joint will be weak. The complete solidification of the solder is indicated by a uniform cloudy appearance forming over its surface. The moment this is noticed and it is usually only a matter of a few seconds' waiting, it is safe to move the work.

Instead of trying to hold the upper strip in position it can be bound down with a few turns of thin black iron wire. This is sold by ironmongers and can be purchased in the same gauge as the bright surface wire used by florists for making up wreaths. The

black appearance of the wire is due to a film of oxide. Such wire is convenient for binding purposes since solder does not stick to it.

128. Method II. By first tinning the surfaces to be united and then heating them.

This method is capable of forming a very strong and almost invisible joint.

Clean the surfaces and treat them with flux. Pick up a globule of solder with the hot bit and rub it into a surface or put a little lump of solder in position and there melt it and rub it about. The surface will be covered with a silver-like film of solder. Treat the other surface in the same way. Place the surfaces together and hold or bind them in position.

Make the bit nearly red hot, but not hot enough to burn off the tinning at its tip, wipe it, and press a wide, clean face of the tip against the upper surface of the horizontal portion of the bent strip (Fig. 142). Heat will be conducted through the strip to the tinned surfaces, the solder on these surfaces will melt and unite. If not quite enough solder appears to be present, keep the bit in position and at the same time push some small lumps of solder against the edges of the joint. If the bit is hot enough these will melt and the liquid solder will be drawn by capillary action into and between the tinned surfaces.

Remove the bit and give the solder plenty of time to set hard before the work is moved.

Instead of applying heat to the tinned surfaces with a bit the work can be heated by application of a Bunsen or blow lamp flame. In this case, rest the work during heating on a sheet of asbestos or dry Uralite tile, and it is best, if possible, to apply heat to the work at a place an inch or two away from the tinned surfaces. Heat will pass by conduction to the surfaces and there is no risk of spoiling the joint by partial oxidation of the solder. During heating it may be necessary to feed a little extra solder into the joint.

A patent composition called 'Soldo,' a combination of flux and solder, is useful for tinning purposes. It can be bought in small tins and is made by Soldo Co., Sicilian House, Southampton Row, London, W.C.1.

With this mixture the tinning of even dirty metal can be carried out with complete success and without difficulty.

After tinning the surfaces with Soldo ordinary solder can be used to complete the joint as described above.

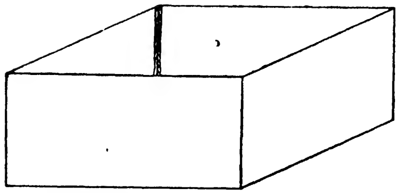


Fig. 139. Tin box with corners soldered on the inside

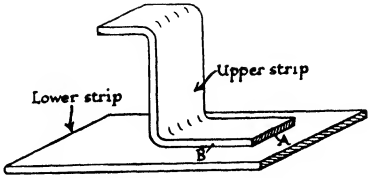


Fig. 140. Strips of brass to be soldered together

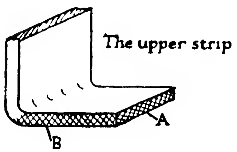


Fig. 141.

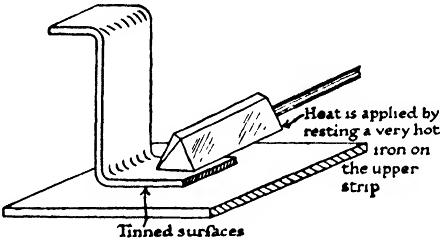


Fig. 142. Method II

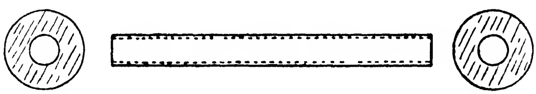


Fig. 143. Tube and bobbin ends for a solenoid

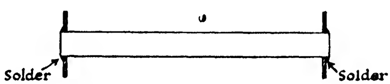


Fig. 144. Completed solenoid tube

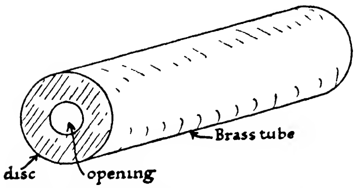


Fig. 145. Method of making an end for a brass tube

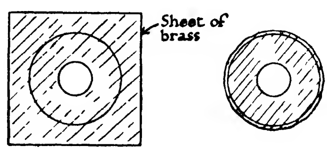


Fig. 146.

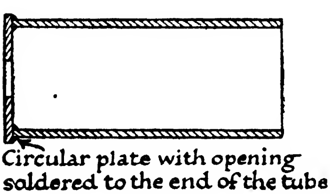


Fig. 147.

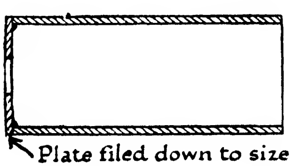


Fig. 148.

129. Method III. By the use of Britinol soldering paste.

This useful material has already been mentioned in Chapter III Sec. **29** under the heading Combined solder and flux.

Clean the surfaces to be soldered and smear them over with a little Britinol paste.

Bind together or otherwise keep the surfaces in contact. Apply a small amount of paste to the outside edges of the joint.

Rest the work on a sheet of asbestos or Uralite and heat it to a fairly high temperature with a Bunsen or blow lamp flame. It is best to apply the flame to a place on the work a little distance away from the surfaces. As heat is conducted to the paste, this will become liquid and may produce fumes that tend to catch fire. If this happens blow the flame out or soot may separate and tend to spoil the joint.

As heating continues, small spheres of liquid solder will collect; go on heating until these spheres run together and form a uniform film. When this is effected, stop heating and allow the solder to set quite hard before moving the work. If insufficient paste has been applied at the start, feed the joint by putting a little more on the edges. The paste can be applied at the end of a nail.

130. To solder the bobbin ends of a solenoid made of non-magnetic material such as brass, zinc or copper. (Fig. 143.)

The central hole in the bobbin ends should be made of such a size that the ends fit tightly on the tube. If loose it is difficult to keep them in correct position during the soldering process. If the holes are too large reduce them in size by the process described in Sec. **69**. Solder each bobbin end in turn with the tube in a vertical position.

If the bobbin is to be wound with fine wire, as evenly as possible, it is best to do the soldering on the outside face of each bobbin end and avoid or file away projections of solder that form on the inside. If the soldering be done in this way it is best to construct the bobbin with the tube projecting about $\frac{1}{16}''$ beyond the bobbin ends. This provides a good surface for the solder (Fig. 144).

131. To solder an end on a brass tube.

A brass tube, closed by a disc at one end, is sometimes required in the construction of optical instruments.

To attach an end with a circular opening in it to a brass tube as shown in fig. 145, proceed as follows.

Measure the diameter of the tube with a pair of callipers. Put a light centre punch mark on a sheet of brass and with this as centre scribe out a circle, equal in diameter to the brass tube. Scribe another circle for the opening (Fig. 146). Make the circular opening. Cut around the large scribed circle about $\frac{1}{8}''$ away. Clean the inside and outside surfaces of the end of the tube. Flux the surfaces to be soldered. Stand the tube vertically on the plate with the large scribed circle just showing all the way round. Solder the plate to the tube (Fig. 147), then file the plate to the outside diameter of the tube (Fig. 148).

132. To solder a circular rod or tube on to a flat surface.

To obtain a strong soldered joint the metals in contact should present sufficient surface one to the other. When designing apparatus this requirement should not be forgotten.

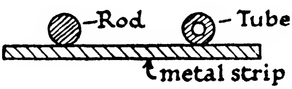


Fig. 149. Poor design for soldering; small surface of contact

Fig. 150. Rod and tube filed to give them each a flat surface of contact with the strip

If a circular rod or tube be soldered on to a sheet or strip of metal the surfaces in contact will be very small (Fig. 149). In such a case it is best, before soldering, to file a flat place on the rod or tube (Fig. 150). If a nut has to be soldered to the side of a rod a curved surface can be filed on the nut with a round file (Fig. 151).

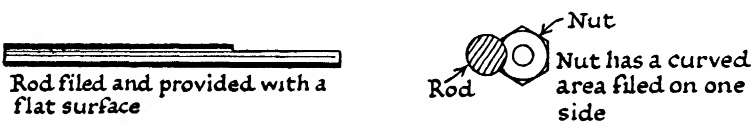


Fig. 151.

133. To solder a Meccano wheel on to a sheet metal disc.

If a brass Meccano wheel provided with a centre boss and set screw be soldered on to a sheet metal disc the latter is readily equipped with an axle. Such discs are very useful for optical illusion, colour and other experiments.

Drill a small hole at the centre of the disc and with the help of a broach (Sec. 89) very carefully enlarge this hole so that a Meccano axle rod will just fit into it.

Arrange the axle, wheel and disc as shown in fig. 152 and solder the wheel to the disc with the axle in position. This makes

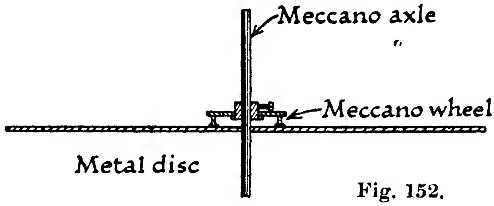


Fig. 152.

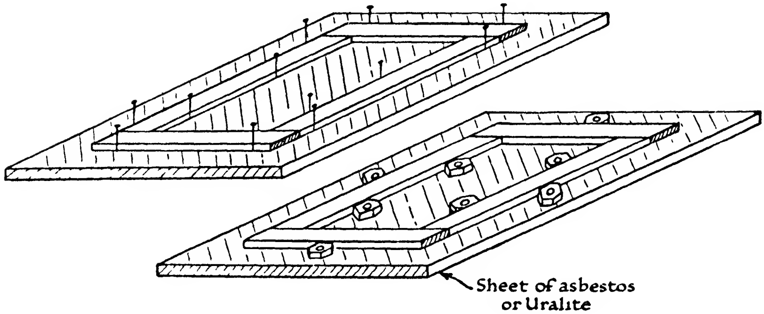


Fig. 153.

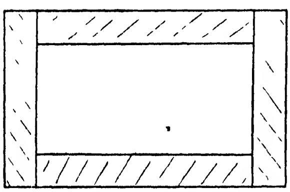


Fig. 154. Frame made of brass strip soldered together

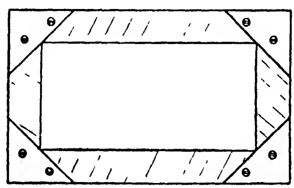


Fig. 155. Frame strengthened with angle pieces

certain of the wheel being attached in a central position. If Britinol soldering has to be used, keep the disc horizontal during soldering and apply heat by conduction through the axle (Sec. **129**). This avoids unequal distortion of the disc by expansion; if it happened to be made of tin plate the direct application of a flame would cause the tin coating to melt and oxidise.

134. The use of Britonol soldering paste for soldering small parts that are easily disturbed and put out of position by the movement of a soldering iron.

A very convenient method of soldering small parts in exact position, one to the other, is to place them on a sheet of asbestos and fix them in position with tiny brads or $\frac{1}{4}''$ Whit. nuts pushed up against the edges (Fig. 153). A steel rule or square can be used to adjust them in position. When everything is correct, carefully

place a little paste over each joint and heat the metal by application of a Bunsen or blow-lamp flame.

A metal frame as shown in fig. 154 can be made very accurately by this method from strip brass. Once the strips are together it is a simple matter if necessary to strengthen the joints by attaching triangular corner pieces with small screws or nuts and bolts (Fig. 155). A piece of Uralite can be used instead of asbestos; it is hard, so brads cannot be employed, but it presents a good flat surface for the use of nuts to prevent movement during heating.

Use a dry piece of Uralite. Uralite recently exposed to the rain is liable to flake when heated strongly and may cause disturbance of the work.

135. To solder electric wires—Electric light and power wires.

Zinc Chloride solution or Baker's Fluid should not be used as a flux in connection with the soldering of joints in electric light and power circuits. For such work use powdered resin or Fluxite.

As a rule, copper wires insulated with rubber are coated with tin and this makes soldering an easy process. Do not remove the tin coating. Before melting solder on to the joint rub powdered resin into the twists of the wire or smear them with a little Fluxite. Fluxite is a trade composition, a brown paste sold in tins. A good way of keeping the paste clean is not to open the lid, but to bore a small hole in the top and extract the flux as required on the end of a match stick. The bit of the soldering iron used for wire jointing can be tinned and dipped into zinc chloride or Baker's Fluid in the ordinary way.

136. Bare copper wire.

Bare copper wires suspended between insulators out of doors, also earthing wires can be soldered with zinc chloride or Baker's Fluid.

Clean them with glass or emery paper before twisting together. Sometimes it is a little difficult to apply solder to horizontal outside wires, in such a case, a convenient modification of a copper bit is to file a wide groove in one face (Fig. 156).

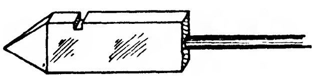


Fig. 156. Soldering iron with groove cut in it for soldering horizontal electric wires

This groove can be tinned and solder melted into it to form a globule. If the bit be held up horizontally below the wire the joint can be bathed in the solder.

137. Electric bell wire.

Zinc Chloride, Baker's Fluid or Fluxite can be used for such wires. If either of the first two fluxes be used, wash the joint after soldering or wipe it with a damp rag to remove all trace of flux and so avoid the possibility of electrolytic or chemical corrosion of the thin wire.

138. To solder very fine gauge instrument wires.

Use powdered resin or Fluxite when soldering such wires (see Sec. **135**).

139. Wireless receiver connections.

Dealers in wireless parts supply straight lengths and coils of bare, tinned copper wire. It can be obtained with a circular or square section, the latter being more rigid. Tinned wire does not require cleaning with glass paper before soldering.

To solder joints of the type shown (Fig. 157) use the minimum of flux.

Zinc Chloride and Baker's Fluid can be safely used for wireless connections if the precaution be taken to apply a very small spot of flux with a pointed brush and to wipe the joint after soldering with a rag. A soldered joint, of a wire on to a terminal end, should appear like (Fig. 158), no solder should spread on to the thread of the screw, so keep the flux away from it and pick up and apply the solder on the tip of a well tinned bit.

140. Flexible electric wire.

Joints in flexible wire are best made by securing the wire or wires with some form of screw connection. Soldered joints are seldom satisfactory. Short lengths of flexible copper wire, insulated with a covering of rubber only, make useful connections for general laboratory work.

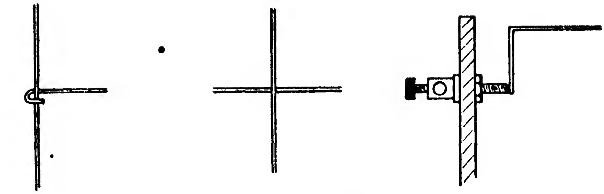
They can be provided with spade connections (Fig. 159). Pass the wire through the sleeve, spread out the end of the wire and only solder this portion, using resin or Fluxite.

141. Moving coil galvanometer suspensions.

The very fine bronze strip and wire connections in moving coil galvanometers can be soldered with the help of a miniature soldering iron.

To make such an iron, obtain a $1\frac{1}{4}''$ length of $\frac{1}{4}''$ external diameter copper tube.

Slip a length of steel rod or thick iron wire to a distance of $\frac{1}{2}''$ or so into the tube and hammer the copper to obtain a tight grip



Wireless receiver connections placed in position for soldering

Wire placed in position for soldering to a terminal

Fig. 157.

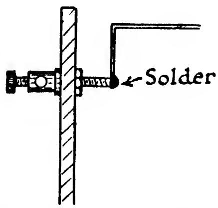


Fig. 158. Wire soldered to a terminal

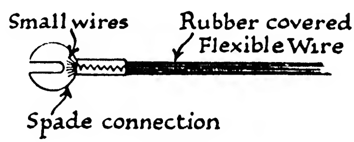


Fig. 159. Soldering a spade connection to flexible wire

(Fig. 160). Close the open end of the tube by hammering and file it to a point. A small wooden handle can be fitted to make the tool easy to hold. Tin the end of the bit and use powdered resin or Fluxite on the instrument connections.

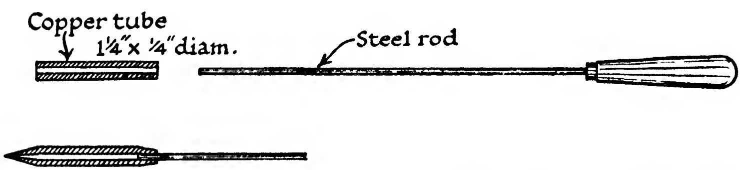


Fig. 160. The construction of a small soldering iron for repairing moving coil galvanometer suspensions

142. To repair a hole in a tin plate kettle.

When repairs are required they are usually in the bottom of the kettle or at the base of the spout.

Clean away all dirt in the way of soot and rust and expose a clean metal surface. Apply flux, zinc chloride or Baker's Fluid, with the help of a brush and solder in the ordinary way.

When making repairs it is wise to prod about and explore for other holes.

Large holes can be repaired by soldering on a patch cut with snips from a tin can or a sheet of tin plate.

143. To solder a tube into the side of a tin can. (Fig. 161).

Make a hole in the side of the can a little smaller in diameter than the external diameter of the tube. A small hole can first be made with a drill and the hole enlarged with a broach or round file. File one end of the tube to a slight taper and push it into the hole to make a tight fit (Fig. 162). Solder in the ordinary way or use Britinol paste. In the latter case keep the tube in a vertical position during the process and heat the joint indirectly by application of a Bunsen or blow-lamp flame to the upper part of the tube.

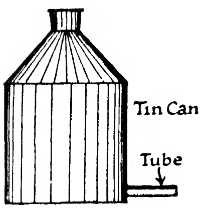
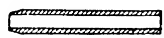


Fig. 161.



Tube prepared for soldering into the side of a Tin Can

Fig. 162.

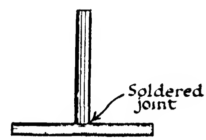


Fig. 163. A T piece made of metal tubing

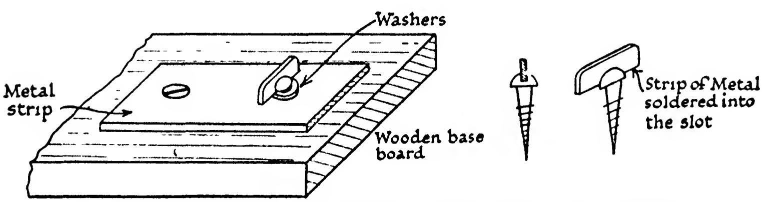


Fig. 164. How to turn an ordinary wood screw into a terminal

144. To solder one tube into another at right angles. (Fig. 163.)

This is very similar to the fitting of a tube into a tin can. Make a hole in the side of one tube, taper one end of the second tube and arrange for a tight fit when it is pushed into the hole.

145. To fit a turn screw top to an ordinary wood screw. (Fig. 164.)

If a short length of fairly strong narrow brass strip be soldered into the slot of a round headed screw it is possible to make a simple terminal. It is best to use round headed screws and to enlarge the slit with the help of a hack-saw or a thin flat file such as a warding file.

Brass or iron screws can be used, but before soldering the latter, remove any black enamel that may be present.

146. Minor difficulties.

Sometimes two threaded objects have to be soldered together so that the threads are continuous.

Example. A steel nut to be soldered to a strip of brass with a threaded hole in it (Fig. 165).

Paint a short length of screwed rod with heat-resisting paint such as Roscoe cylinder black or ordinary stove enamel. Dry over a flame. Screw the nut and block on to the rod (Fig. 166), and then solder the nut to the block. Remove the rod. The paint prevents the solder from adhering to the rod.

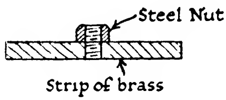


Fig. 165.

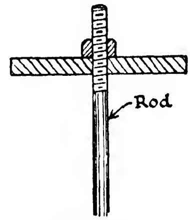


Fig. 166.

If, when soldering, it is found that the heat applied to one joint causes another one to come unfastened, it is usually possible to overcome the difficulty by using the bit at a rather higher temperature than usual, so that a momentary application of the bit is sufficient to melt the solder. If this be not successful, the joint that comes unfastened can be kept cool by placing a strip of wet blotting paper on it.

147. Solder and files.

Try to avoid the use of good new files on solder, it quickly clogs them and spoils the cutting power. A file brush cleaner made of steel wires can be bought for about 6d. and this is of some help in brushing a clogged file. An ordinary pocket knife is one of the best tools for paring away excess solder, but it is far better to avoid excess in the first instance.

148. Unsoldering.

The wires soldered to the terminals of old second-hand electrical apparatus can be detached by the application of a hot bit. Solder on the threaded portion of terminals can be removed by heating the terminal in a flame, when the solder becomes fluid it can be wiped off with a cloth. If this method be not convenient the thread can be cut clear with a die.

149. Building up with solder.

By the careful soldering of one piece of metal on to another one it is often possible to build up an object that might, without the help of solder, require the preparation of a casting or the use of machine tools.

150. To solder brass gas pipe on to composition tubing.

Expand the composition tubing as shown in fig. 167 and file a slight bevel on the brass pipe. Tin the end of the brass pipe, then place it in position. Treat the outside of the brass pipe and the inside surface of the composition tubing with Fluxite. Place in position as shown in fig. 168.

Apply a hot iron to a stick of tinman's solder and drop globules of molten solder into the space between the pipe and the tube. Heat the brass pipe at a point a few inches away from the joint to be formed. Heat will be conducted to the solder; after a short time it will melt and on cooling will make a perfect junction (Fig. 169).

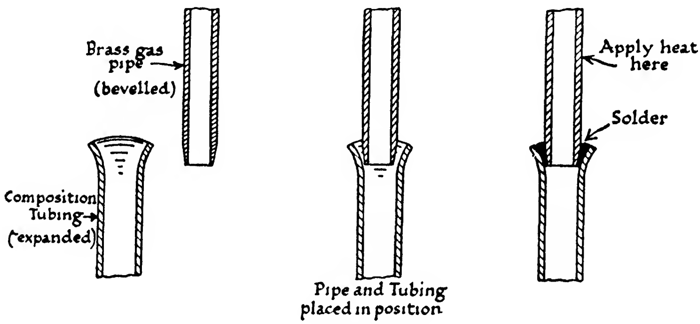


Fig. 167. Fig. 168. Fig. 169.
Method of soldering brass gas pipe into composition tubing

CHAPTER VII

WOODWORKING

151. Some methods of obtaining practical knowledge.

THE construction of apparatus often calls for a combination of both wood and metal, but the amount of woodworking required is seldom very extensive unless the construction of laboratory furniture be embarked upon.

If a high degree of finish be not required even lecture tables, benches and stools can be made in a school wood-shop.

Many excellent books have been written on the art of woodworking, one of the best being *Woodwork Tools and how to use them,*[1] and no attempt is made in the present volume to deal in any detail with a subject already so well described.

Anyone wishing to gain a knowledge of woodworking can, without much difficulty, teach himself from a careful study of books and by practice with tools. A more rapid method of learning is to pay for a few lessons from a good carpenter or cabinet maker, and to combine these with reading and practical work.

In this chapter attention is drawn to certain forms of wood of particular value in the construction of apparatus and a few notes are given on elementary woodworking processes.

The mastery of these few processes will, with very limited equipment, enable the science worker to overcome most of the woodworking difficulties likely to be encountered in apparatus construction such as baseboard making and simple box work.

152. Wood supplies.

Timber merchants supply wood of different kinds both planed and unplaned and in many widths, lengths and thicknesses. Wood in these days is so rapidly planed by machinery that the cost of wood so prepared is little more than that of the rough material and planed wood saves much time and trouble.

A plank of wood that measures $\frac{1}{2}''$ thick in the rough condition will measure about $\frac{7}{16}''$ thick when planed. If planed boards be ordered it is well to remember this.

Timber is usually sold at so much the foot length. For bench

[1] By William Fairham; Evans Brothers Ltd., Montague House, Russell Square, W.C.1. 3/6.

construction, shelves and other rather heavy work ordinary deal is very suitable and cheap. American whitewood, the various forms of mahogany, and oak are all good woods to use in connection with apparatus construction.

American whitewood is particularly useful; cheap, easily worked and very free from knots. It can be obtained in wide planks and has a high electrical resistance. The light colour is not very pleasing and unless stained or varnished shows finger marks.

For good effect it is difficult to rival mahogany. It does not show finger marks and is easily given a good finish by simple processes (see Sec. **203**). Honduras and African mahogany are the best varieties to use. When purchasing timber it is well to inspect it for cracks, knots, rough irregular grain, freedom from warp and uniformity of thickness. Birch plywood is a most useful material and can be obtained in large and small panels. A large panel may measure as much as $5' \times 4'$, and yet have a perfectly uniform surface.

Plywood is very rigid, even when thin it shows little or no tendency to warp, the surfaces are smooth, require no planing and are easy to mark out. The most useful thicknesses to keep in stock are 3 ply $\frac{1}{4}''$ thick, 5 ply $\frac{3}{8}''$ thick, 7 ply $\frac{1}{2}''$ thick.

Another useful, but rather expensive form of wood is strip wood. This can be obtained in many different sections. It should not be regarded as a lazy man's method of escaping from the labour of preparing strips in the ordinary way, but its use, on occasions, saves time, and its accurate form is an asset.

Hardwood dowel-rods to be obtained from ironmongers, builders' merchants, or the firms mentioned at the end of this chapter, can be used in the construction of many forms of apparatus. They can be bought in lengths up to $3'$ long, and varying in diameter from $\frac{3}{16}''$ to $1''$.

The teak baseboards used by electricians for the wall and ceiling attachment of electrical fittings sometime make convenient bases for instruments. The recess below gives room for wires and terminal nuts.

153. The preparation of baseboards.

Let us suppose that two baseboards are required, each measuring $6'' \times 10'' \times \frac{1}{2}''$. First decide on the form of timber to be used. Planed or unplaned timber, plywood, American whitewood, mahogany. Since the boards are to be $\frac{1}{2}''$ thick when finished it will be necessary, if unplaned wood be used, to obtain it about $\frac{3}{4}''$ thick, to allow for hand planing. The edges of the board in any

case will be rough, so allowance must be made for this. A piece of plank 4′ long and 8″ wide will yield the material required and by careful sawing some useful portions will be left over.

Inspect the timber, examine it for cracks and bad places. If bought unplaned go over one side with a smoothing plane. Before marking out, plane one of the long edges to give a true surface for the carpenter's square. This can be done with a smoothing plane, but the proper tool to use is a jack plane.

When marking out wood try, if possible, to arrange that any portions left over will have a useful shape. Economy can be effected in this direction.

Mark with a pencil in conjunction with a square and steel rule. Make the lines AB and CD $\frac{1}{4}''$ apart and draw HM about $\frac{1}{8}''$ away from EG (Fig. 170).

Support the wood on trestles or between laboratory stools and use a hand saw to cut out the boards. Cut at a distance of about $\frac{1}{8}''$ from the pencilled outline of the boards, and avoid spoiling the spare wood by sawing too far.

After planing the reverse side of each board, clamp it in a vice and plane down to the lines. Plane the ends showing cross grain before doing the long sides.

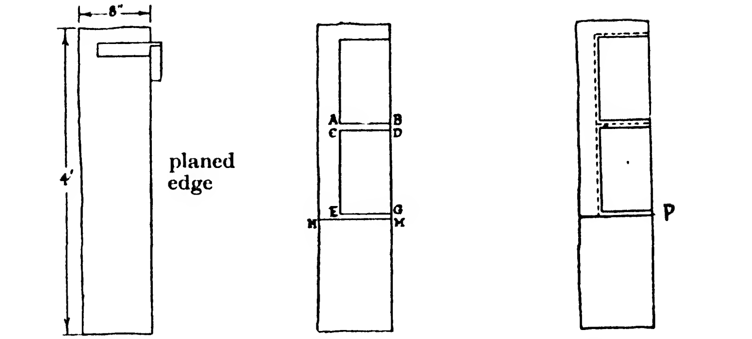
All these processes are very simple, but a few observations may be helpful to the beginner.

An ordinary parallel vice, item No. 20 or 21 in the 'A' tool list can be used for holding wood, a woodworker's vice, item No. 31 is very convenient, but not essential. If jaw protectors are used the wood will not be marked.

A good form of protector that, with advantage, extends the area of the clamping surface is shown (Fig. 172). This can be made of wood. The rectangular notch is cut out to fit over the square part of the vice and prevents the clamp falling off when the vice jaws are opened.

The notch can be formed by making two vertical saw cuts to A and B with a tenon saw followed by chisel cuts along AB (Fig. 171). A hand saw (item No. 60) makes a rougher cut than a tenon saw (item No. 61). A tenon saw is very useful for cutting across the grain of wood, also for cutting ply wood or wood that is to be injured as little as possible by the sawing process. The strengthening bar on the back of a tenon saw tends to limit the length of cut that can be made with such a tool (Fig. 176).

When using a hand saw to cut to a corner as at A in fig. 173, it should, during the last few stages of the cut, be brought into a vertical position, this brings the bottom of the cut at right angles



The start of the marking out process

Method of marking out

Saw along dotted lines and across the plank at P

Fig. 170 The preparation of a baseboard

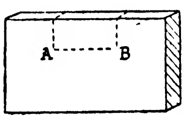
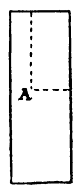


Fig. 171. Method of construction



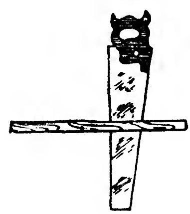
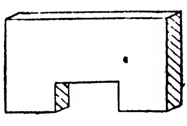


Fig. 173. Position of hand saw during the last stages of the cut



Direction of grain

Fig. 172. A wooden protector for vice jaws

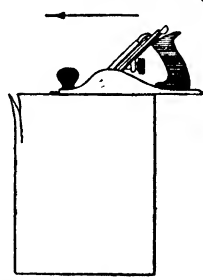


Fig. 174. Effect of careless planing across the grain

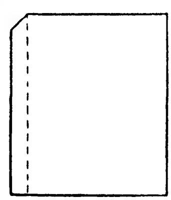
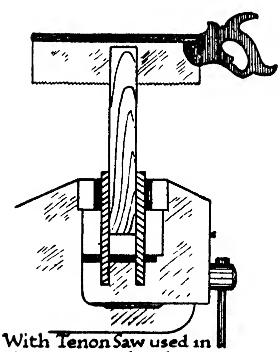
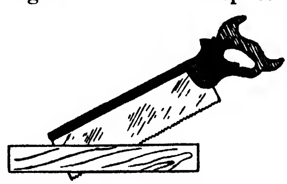


Fig. 175. A method of preventing splitting



With Tenon Saw used in this position depth of cut is limited



A long cut can be made with saw in this position

Fig. 176.

to the surface, it avoids sawing beyond the mark and so spoiling the spare wood.

When sawing off a piece of wood take care to support it during the last stages.

154. Using planes.

If an adjustable steel plane be used the blade can be set to cut a thick shaving when rough wood has to be planed, then, as the surface being worked becomes smoother, the blade can be brought in by means of the adjusting screw.

When planing on the end grain of wood there is always a danger of splitting it away on the far corner (Fig. 174).

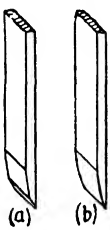


Fig. 177.
(*a*) A good edge
(*b*) A rounded edge, showing the effect of rocking during sharpening

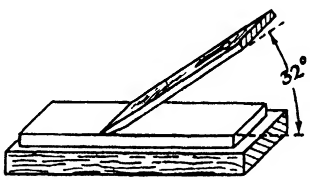


Fig. 178.
Position of plane iron during sharpening

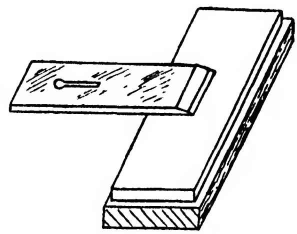


Fig. 179.
Removing the wire edge

HOW TO SHARPEN A PLANE IRON

It is best to plane a little over half way across, then reverse the wood in the vice and plane from the other corner.

One method of avoiding a split is to bevel the far corner with a chisel (Fig. 175).

Take great care not to chip bits out of the plane iron by hitting it on nails, screws, the top of the vice or an iron bench stop. Bad chips have to be removed by grinding the plane iron on a wheel, less serious damage can be repaired by grinding on a flat carborundum stone, using plenty of thin engine oil as lubricant.

When the chip has been ground out, the plane iron can be sharpened on an ordinary oil stone.

When sharpening, care has to be taken not to give the iron a rocking motion or the end will look like fig. 177(b) instead of (a).

The plane iron should be held with the right hand and worked up and down on the stone at a constant angle of about 32°, pressure being applied with the fingers of the left hand (Fig. 178).

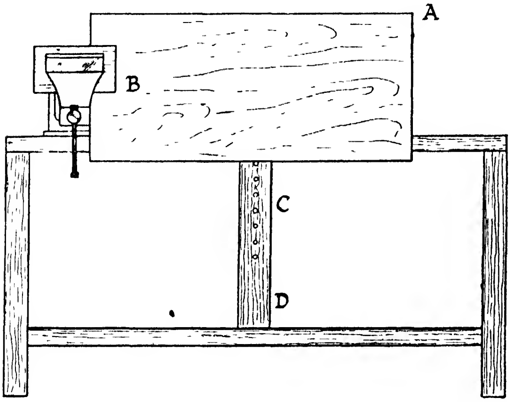
During sharpening the iron should be given a side to side in addition to the rubbing motion. The process of sharpening usually

takes about five minutes, when the edge appears to be correct, turn the iron over and wipe the flat side on the oil stone to remove the wire edge (Fig. 179). A quick strop on the palm of the hand or on a razor strop will remove the last trace of the wire edge.

Use a jack plane for the long edges of flat boards and a smoothing plane for short ones. A jack plane yields a truer edge when conditions enable it to be employed.

A useful bench fitting for the support of long boards can be made by fixing a 1″ thick board to the side of the bench and providing it with holes to take short lengths of dowel rod.

When a board has to be held in a vice, possibly an engineer's vice, one of the dowel rods can be tapped out from a hole to form a support (Fig. 180).



A. board held in position for planing the top edge
B. clamps
C. dowel rods
D. board secured to the side of the bench

Fig. 180.
A useful method of support when planing the edges of long boards

After planing an edge it should be tested for truth by means of a square and any error should be corrected before it is too late by taking off shavings in appropriate places (Fig. 181). It is often a help to accurate working with a plane to mark a piece of wood that is being prepared, not only on one side, but all the way round. A 6″ engineer's steel square is very useful for this purpose.

155. Using screws.

The form of screw of greatest value in connection with woodwork is the countersunk head type (Fig. 36).

Small screws can be screwed without previous preparation into soft wood, but as a general rule it is best to drill a hole first. The selection of the correct twist drill to use is akin to the visual selection of the correct tapping drill to use when cutting a screw thread (see Sec. **104**).

The diameter of the drill should equal the distance AB (Fig. 182). It is sufficiently accurate to make a selection by holding a drill and

a wood screw up to the light. If the precaution be taken of drilling wood with the correct drill before attempting to insert a screw it is possible to screw large screws into hard wood without any difficulty and in the case of thin wood and ply wood, no

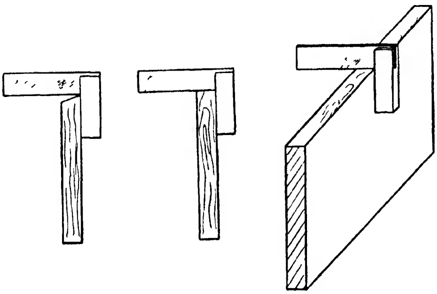
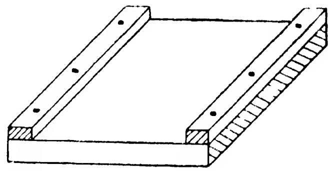


Fig. 181. The edges should be tested for truth with a square

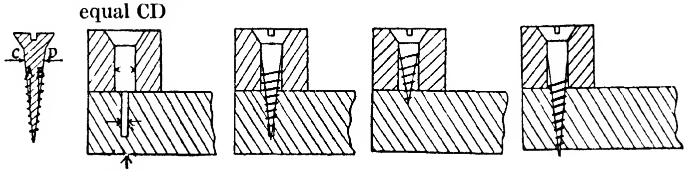


Strips of wood attached to the underside of a baseboard

trouble will arise from splitting. Holes for screws can be countersunk with a rose bit used in a carpenter's brace (Items No. 72 and No. 65 in tool list).

When one piece of wood has to be screwed to another one, for instance when attaching strips to the underside of a baseboard, the piece of wood to contain the countersunk holes should be drilled out to the diam. of the upper part CD of a screw (Fig. 182).

This diameter should equal CD



This diameter should equal AB

correct length too short too long

Fig. 182. The use of screws

First mark out, drill and countersink the holes for the screws in the strips. Place a strip in position, drop screws through the holes and mark the position of the drill holes in the baseboard by giving each screw a slight tap with a hammer.

If a screw be too long, so that its point comes through on the far side the tip can be filed away, for preference before rather than after insertion. When available, screws of the correct length should be used.

156. Use of screws for making cases.

A cabinet maker would construct the case of a resistance box

by dovetailing the corners. A box supplied by an instrument firm would probably be dovetailed by machinery.

A strong case can be made by screwing the corners together. After the pieces of wood have been prepared as true as possible and the time comes to fasten them together proceed as follows. Place two pieces in position and draw a pencil line along XY (Fig. 183). Remove the top piece and mark the position of the holes for screws (Fig. 184). Select a screw of suitable size and find a drill of diameter CD (Fig. 182). Drill at the marked positions. Turn the wood over and countersink the holes.

Clamp P in a vice. Hold M in position. Press screws through the holes and so mark the end of P (Fig. 185). Remove M (Fig. 186). Drill at the marks using a drill of diam. AB (Fig. 182). Make the holes deep enough. Now screw M on to P. Use a screwdriver that fits the slots in the screws and one that is not too large to allow the screws to be countersunk (Fig. 188).

Apply this method of screwing to attach the other sides and the base (Fig. 187).

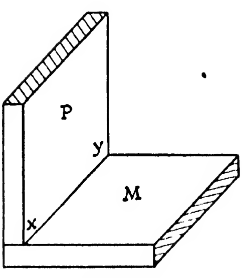


Fig. 183.

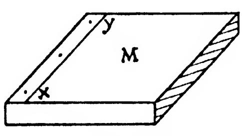


Fig. 184.

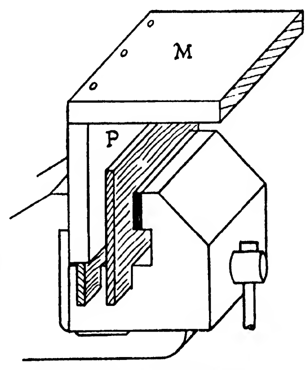


Fig. 185. Screwing a box together

157. Hinges.

The fitting of hinges requires a little care. Place the hinges in position as shown (Fig. 189), and pencil a line round each one. They must be so placed that the centre of each hinge comes over the outside edge (Fig. 190).

Take the hinges away and make a shallow cut with a sharp chisel along AB, CD, EG, and HM (Fig. 191). This done cut along BD and GM carefully, and remove enough of the wood to enable one half of each hinge to fit in just flush with the surface (Fig. 192).

Attach the hinges to the box side with screws (Fig. 193). Now

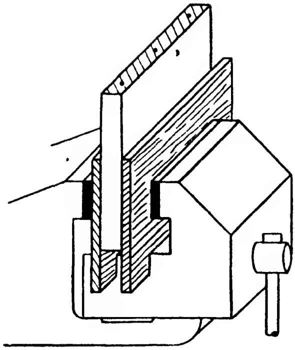


Fig. 186.

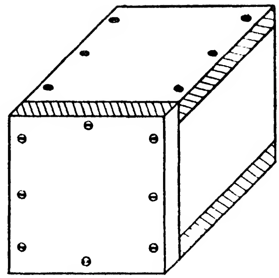
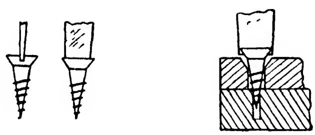
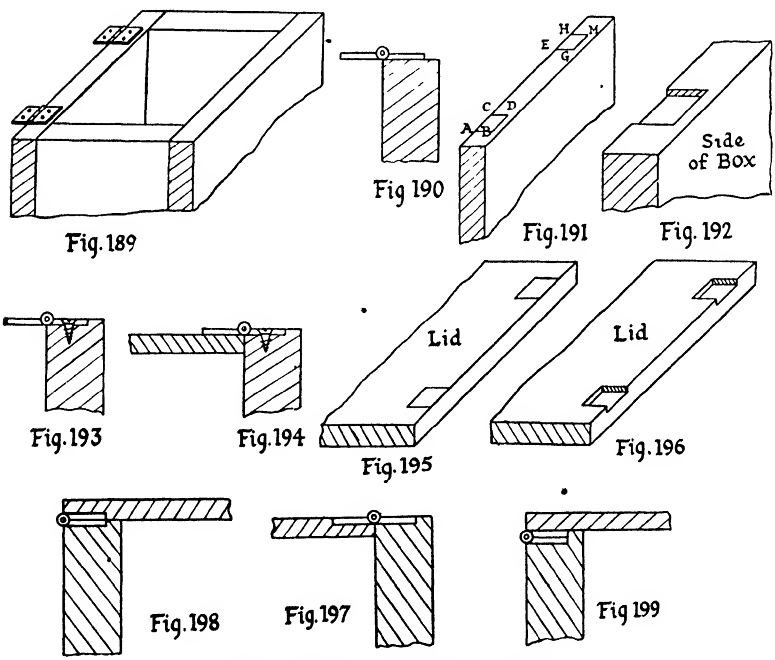


Fig. 187. The finished box with sides fastened together with screws



In this case the blade of the screwdriver is too wide

Fig. 188. How a screwdriver should fit a screw



Figs. 189–199. How to fit hinges

place the lid in position as shown in fig. 194, and pencil the outline of the hinges on the lid (Fig. 195). Cut the wood away as before to allow the hinges to fit in flush (Figs. 196 and 197), then attach them with screws. The lid should close as shown (Fig. 198).

An alternative method is to cut the wood of the box side to a depth equal to the thickness of the closed hinge. This avoids cutting the lid (Fig. 199).

158. The use of tools for making holes in wood. Gimlet and Bradawl. (Items 74 and 75 of tool list.)

For making starting holes for screws in soft wood a gimlet or a bradawl can be used. When using a bradawl close to the end of a piece of wood it should be inserted with its blade across the grain, it is then less likely to start a crack (Fig. 200).

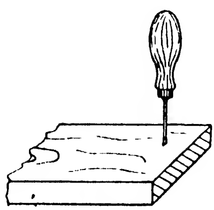


Fig. 200
How to use a bradawl

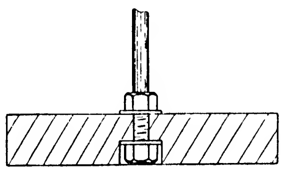


Fig 201

Fig 202

Fig 203

Fig. 204

Preparation of baseboard

159. Brace, auger bit and centre bit. (Items 66–68 and 69–71 of tool list.)

Long holes in wood are quickly bored by means of a bit fitted into a carpenter's brace. For normal use take care to keep the bit vertical to the surface of the work. The ratchet mechanism of a brace makes it possible to use the tool in a confined space or corner.

An auger bit tends to produce a ragged edge at the place where it emerges and the sides of the hole are left rough. If a clean hole or a hole with a flat bottom be required use a centre bit.

Fig. 201 shows a rod attached to a baseboard. The space for the bottom nut is cut with a centre bit. First drill a small hole about $\frac{1}{32}''$ diameter at the place where the rod is to be fitted (Fig. 202). Turn the wood over. Cut the space for the nut with a centre bit (Fig. 203), then drill out the original hole to full size $\frac{1}{4}''$, $\frac{3}{8}''$ as the case may be according to the diameter of the rod (Fig. 204). If the hole for the rod is made full size at the start the

point of the centre bit will wander about and it will be impossible to cut a clean space for the nut.

If a centre bit be used to make a hole right through a piece of wood proceed as follows.

Place the piece of wood on some odd scrap that it does not matter cutting, not directly on the bench top.

Use the centre bit until the point just appears on the under surface (Fig. 205). Reverse the work, place the point of the bit in the small hole made from the other side and make a light cut into the wood with the edge of the bit (Fig. 206). Turn the work over again and complete the cutting process from the original side

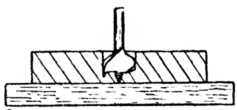


Fig 205

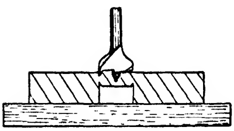


Fig. 206

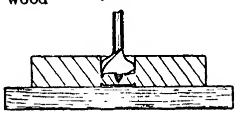


Fig 207

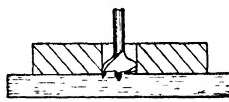


Fig. 208

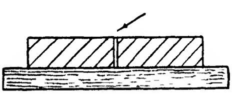


Fig 209

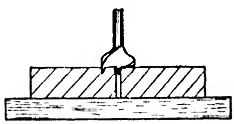


Fig. 210

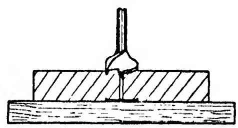


Fig 211

(Figs. 207 and 208). If the bit be used without taking these precautions the wood on the bottom side is liable to tear away as the bit emerges.

A second method, and one that saves the trouble of stopping and turning the work over from time to time to see if the point of the bit has appeared, is first to drill a small hole of about $\frac{1}{32}''$ diameter right through the wood (Fig. 209). Reverse it, make a light cut with the centre bit (Fig. 210). Turn the wood over again and complete the cutting with the centre bit from the first side (Fig. 211).

160. Twist drills.

Twist drills are just as suitable for drilling holes in wood as in metal. They do not crack or splinter the wood and for this reason alone are in constant demand. Twist drills can be bought with shanks to fit a carpenter's brace (Fig. 212). Drills up to

$\frac{1}{4}''$, with straight shanks, are best held in a hand drill or drilling machine.

Fig. 212

161. To cut large holes. Use of keyhole saw.

Large holes in wood can be cut in a variety of ways. One method is to use a keyhole saw. Outline with a pencil the opening required and drill or bore a hole in the part cut to waste to allow for the insertion of the saw blade (Fig. 213). Saw round the mark. The saw leaves rather a rough surface and edge. The surface and rough edge left on ply wood can be smoothed by the application of glass paper. On ordinary wood a flat shaped or a half round bastard file is often useful for cleaning up before glass papering.

162. Use of fretsaw.

Holes of any shape and size can be cut in thin wood up to $\frac{1}{4}''$ thick by the use of a fretsaw. $\frac{1}{4}''$ thick 3-ply wood is easily cut with a fretsaw. The blade is held and tensioned in a special frame (Fig. 214), and has to be given regular movement without the application of undue force. Blades are easily broken by the inexperienced. The wood being cut can be held in a vice or supported on a special table with a V-shaped opening (Fig. 215).

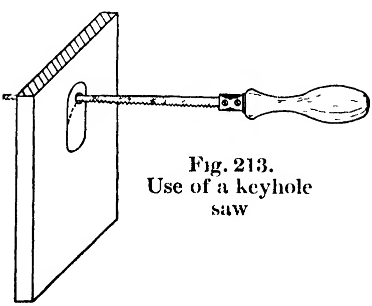


Fig. 213. Use of a keyhole saw

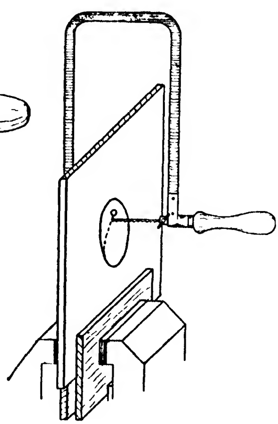


Fig. 214. Use of a fretsaw

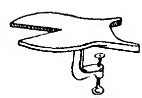


Fig. 215. Sawing-table for use with a fret saw

By courtesy of Hobbies Ltd.

163. Use of a leather washer cutter to cut large holes in wood.

A leather washer cutter (Fig. 216) is useful for cutting circular

holes in thin, $\frac{1}{4}''$ thick, 3-ply wood and for such work is very much quicker and better to use than a fretsaw. The cutting blade can be adjusted to cut holes up to $12''$ in diameter. To use the tool set the blade to the necessary radius and clamp it so that the bottom edge is about $\frac{1}{8}''$ higher than the point of the tool (Fig. 216). The tool is held in a carpenter's brace. Place the point of the tool on the centre of the hole to be cut and rotate with steady pressure. The wood being cut should be supported on a flat board and the best position can often be obtained by doing the work on the floor.

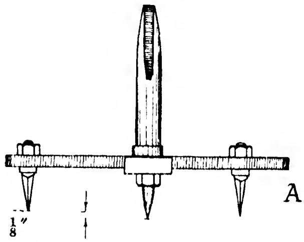


Fig. 216. Leather washer cutter
By courtesy of Wynn, Timmins & Co Ltd.

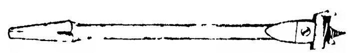


Fig. 217. Clark's Patent Expansive Bit

The cut may be made from one side or the work can be turned over and cut half from one side and half from the other. The latter method gives a slightly cleaner edge. A tool for cutting large circular holes in thick or thin wood is known as Clark's Patent Expansive Bit (Fig. 217). It is expensive, but does its work well. A bit boring from $\frac{7}{8}''$ to $3''$ is a useful size.

164. Chisels.

Chisels of the firmer type are the most useful in a laboratory workshop. They can be bought with bevelled or plane edges. Bevelled edge chisels are not as strong and are more expensive than the plane ones, but are capable of finer work (Fig. 218).

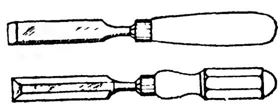


Fig. 218. Firmer chisels

Chisels are sharpened in the same way as plane irons (see Sec. **154**), but without the side to side motion. The chisel should not be rubbed up and down over the same area of the stone all the time or a hollow will eventually be formed in the latter.

During sharpening try to keep the pressure equal on the two corners of the edge otherwise the latter will tend to be ground out of square.

The handle of a chisel should never be hit with a hammer, it is liable to split the wood, use a wooden mallet.

When using a chisel for paring away wood hold it as shown in fig. 219, keep the left hand behind and so out of danger from the cutting edge. Put a piece of scrap wood under the work to avoid damaging the bench top.

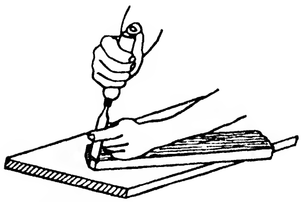


Fig. 219. How to pare wood with a chisel

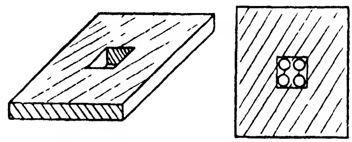


Fig. 220. A square opening in a base-board made by first boring with a brace and bit and then cutting with a chisel

A combination of boring with a brace and bit and cutting with a chisel is a common method of procedure (Fig. 220).

165. The spokeshave.

A spokeshave is used for shaping a curved edge and is held as shown (Fig. 221).

It is useful for shaping the edge of circular discs cut from ply wood. The disc can be cut roughly to shape by means of a tenon saw and finished to the guide line with a spokeshave.

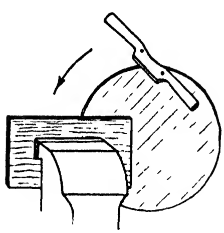


Fig. 221. Use of a spokeshave

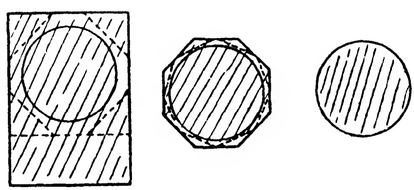


Fig. 222. How to cut a disc, using a saw, chisel and glass paper

If a spokeshave be not available it would be possible to cut out the disc to rough shape with a saw and bring the edge into good condition by paring with a chisel followed by glass papering (Fig. 222).

166. Bench hook.

A bench hook (Fig. 223) can be easily home made and is most convenient to support work on and prevent it from slipping when tenon-sawing.

167. Mitre Block and Picture Frame making.

The use of a mitre block (Fig. 224) makes the construction of picture frames a very easy business. Picture frame moulding can be bought for a few pence per foot or moulding of simple section can be made in any carpenter's shop. The moulding is cut at the requisite angle, 45°, by holding it firmly against the face A of the block and using a tenon saw, guided at the correct angle by one of the slots in the block. The end faces of the frame sections are glued and fastened with brads (Fig. 226).

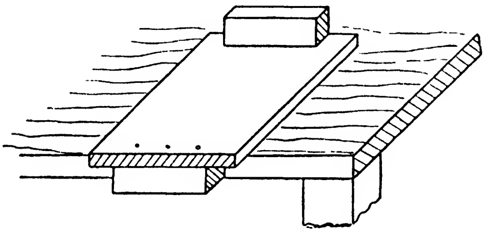
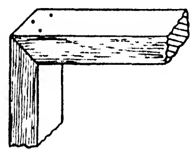


Fig. 223. A bench hook



Brads are shown as dots

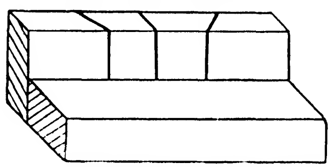


Fig. 224. A mitre block

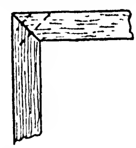


Fig. 226.

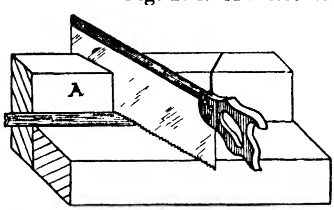


Fig. 225. Method of using a mitre block

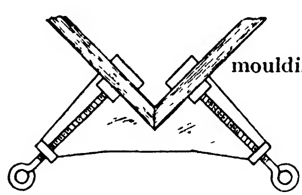


Fig. 227. A mitre cramp

During the hammering in of the brads each of the four sets of faces have to be held together in turn and prevented from slipping. This with care, can be done by holding the moulding in a vice. A mitre cramp can be bought at a cost of about 1/6, this holds the moulding securely without risk of damage (Fig. 227).

For picture frame work it is best to use a tenon saw with fine teeth, such a saw leaves a clean edge.

168. To fix a dowel rod in a baseboard (Fig. 228).

Use a twist bit, held in a carpenter's brace to bore the hole for the dowel.

The bit must be a of a size to bore a hole having a diameter equal to that of the dowel.

Make a shallow saw cut in the side of the dowel to enable air and excess glue to escape. This is only necessary when the bored hole is a blind one (Fig. 229).

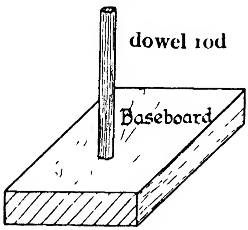


Fig 228

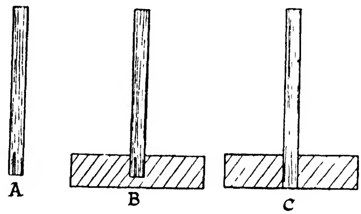


Fig 229

A. Saw cut to allow air and glue to escape
B. Dowel fitted into a blind hole
C. Saw cut not necessary

Care must be taken to keep the bit vertical to the face of the board or the dowel will be out of the vertical when fixed in position. Bore slowly and use a try-square to test the squareness of the bit with the work.

Glue the end of the dowel, put a little glue inside the hole then force or tap the dowel into position.

169. Glass-papering.

Glass paper is best used on flat surfaces by wrapping it round a rectangular block of wood or cork measuring about $5'' \times 2\frac{1}{2}'' \times 1\frac{1}{4}''$. The block makes it easy to hold and the paper is kept flat (Fig. 230).

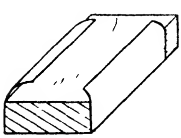


Fig. 230. A block for glass papering

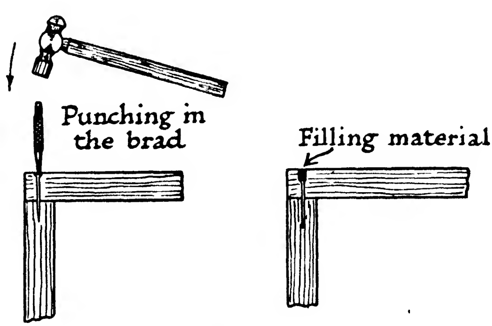


Fig. 231.

170. Nails. (Oval steel brads.)

It is best as a rule to use screws instead of nails, but sometimes

they are convenient and save time. Oval steel brads (Fig. 40), are inconspicuous and can be made quite invisible by punching them down, a little below the surface. Use a fine nail punch (price 2d.), or a short length of steel rod (Fig. 231).

The small hole left by the punch can be filled in with beeswax, putty or Plastic wood.

171. Plastic wood.

Plastic wood is a commercial preparation sold in tubes and tins. It is useful for filling up holes in wood, but has the disadvantage of drying up very easily when kept in store unless the tube be well sealed or the lid pressed down tightly. It is best bought in a tin, then, if the contents become dry they can be brought into condition again by adding some of the softening fluid sold by the makers or by the addition of acetone.

172. Gouges.

Gouges are occasionally required for wood work and are of service in a laboratory for cutting out leather washers (Fig. 232).

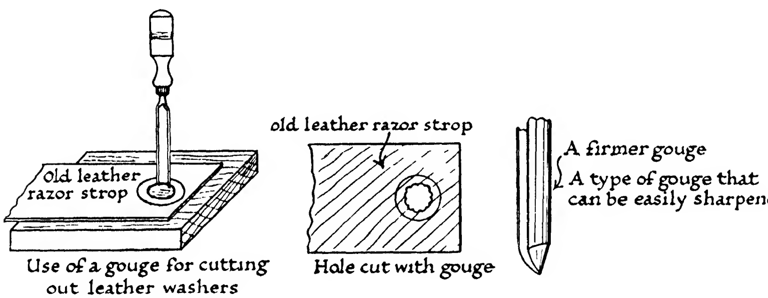


Fig. 232

Good washers can be cut from old razor strops, the circles being marked with a pair of steel dividers. The inner circle can be cut with a gouge and the outer one with scissors.

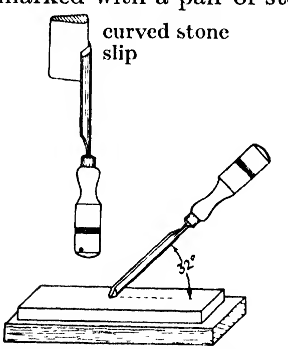


Fig. 233. Sharpening a gouge

A firmer gouge can be sharpened on an oil stone in much the same way as a chisel, except that a semi-rotary motion must be given to the tool as the end of the blade is rubbed up and down.

The wire edge that is formed on the inside can be removed by pressing a little curved stone slip into the hollow of the gouge. The slip is then moved up and down (Fig. 233).

CHAPTER VIII

ELECTRIC WIRING AND THE LABORATORY

In a laboratory where much experimenting is going on it is often necessary to make electrical connections to the main supply and to modify or extend old circuits.

Some knowledge of the art of the electrician is useful. To the science worker, so provided, the main supply soon ceases to be regarded with awe.

173. Buying electrical fittings.

During recent years many fittings moulded in Bakelite have appeared on the market. To a casual observer a 6d. tumbler switch may look as good as a 1/6 one. Fittings should be examined for the quality of their contacts and general inside finish. The small screws in cheap fittings are often faulty and sometimes they have sharp edges that will cut through flexible wire. Inspect new lamp-holders and switches to make certain the binding screws are present, they not infrequently drop out in the packing. Switches are made to carry a current up to a maximum value without overheating. A 5-ampère switch should not be expected to carry 10 ampères for more than a short time.

The ordinary electric switch will carry 5 ampères without any sign of heating.

Flexible electric wire is usually referred to at an electrician's shop as lighting flex or power flex. Lighting flex will carry 5–7 ampères and is suitable for all ordinary electric light work where flex is required. Power flex is suitable for electric heating apparatus and will carry 10, 15, 20 or more ampères according to size.

If the power required to work the apparatus be known, also the voltage of the supply it is a simple matter to work out the size of wire to use.

Example. An electric projection lamp is marked 800 watts.

$$\text{Voltage} = 200 \qquad \text{Current (ampères)} = \frac{\text{Power (watts)}}{\text{Voltage (volts)}}$$

$$= \frac{800}{200} = 4 \text{ ampères.}$$

Such a lamp could be wired with lighting flex and connected to the lighting circuit without danger of blowing the fuse.

The size of flexible wire is specified by two numbers, such as 10/32; this means that it is made up of 10 strands of wire each of No. 32 Imperial Standard Wire Gauge.

Cotton-covered flexible is cheaper and more durable than silk-covered flexible, and maroon is the best colour for not showing finger marks. It is much cheaper to buy flexible wire in 50 yard coils than by the yard.

174. Wiring a lamp holder.

This apparently simple operation requires care and is seldom properly carried out by the beginner.

Examine the flex to be used and if necessary cut the end to leave a clean unravelled length. Untwist the two portions to a

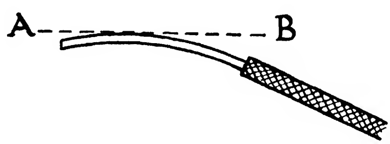


Fig. 234.

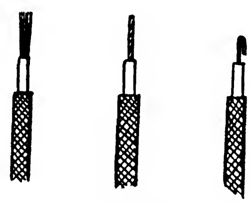


Fig. 235.

distance of about 2″. Push back or cut the cotton covering to expose the rubber. The covering is best cut with a pair of scissors. Bend the wire over (Fig. 234) and with fine scissors cut tangentially along AB. The rubber can now be pulled away. It is better to cut the rubber in this way instead of attempting to get it off with the finger nail or by pulling it.

Take care not to cut any of the fine wires or a stray end may be left and possibly give rise later to a short circuit.

Remove any cotton covering or strands of cotton that may be exposed after taking off the rubber. About ½″ of wire should be bared; twist the strands of each wire and double them back as shown (Fig. 235).

Push the wires into the brass terminal holes of the holder and tighten up the binding screws. The wires should be pushed in far enough to prevent any bare wire showing on the non contact side of the porcelain (Fig. 236), and care must be taken not to tighten the screws with undue force or they may cut through the wire. Before assembling the parts of the holder, test each wire attachment by giving it a slight tug.

If the far end of the flexible wire be already attached to a ceiling rose or other fitting, it is usually necessary to slip on one or more parts of the holder before making the terminal connections. The indentations of the porcelain part B (Figs. 236 and 237)

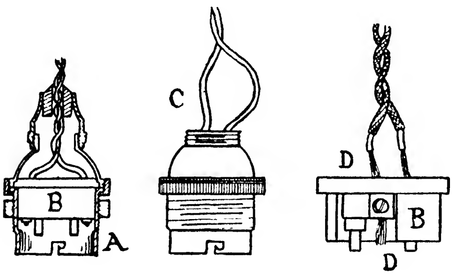


Fig. 236.

(a) Good wiring—no bare wires showing (b) and (c) bad wiring; no cord grip at C wires of unequal length; bare wires showing at D

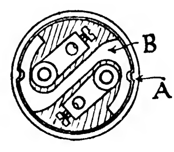


Fig. 237.

View looking into lamp holder. Indentation in B must coincide with projection on A

HOW TO WIRE A LAMP HOLDER

must coincide with the projections on A, or a lamp placed in the holder will not make contact and so fail to light. Lamp holders of modern design are contrived to grip the flexible and take the pull away from the terminals without the need for fitting in two bits of wood. If an old type holder is being wired, always insert the halves of the wooden cord grip. If necessary enlarge the grooves in the wood by filing them with a small round file.

The binding screws of lamp holders that incorporate a switch are sometimes difficult to replace if they are inadvertently unscrewed too far.

A method of keeping a screw in position for the purpose of starting and replacing it is to make a holder out of a strip of paper. Once the threads have engaged the paper can be torn away (Fig. 238).

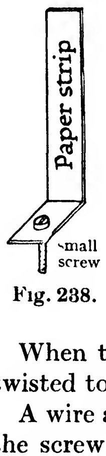


Fig. 238.

175. Ceiling rose connections.

Two lamps can be connected to one ceiling rose as shown (Fig. 239).

When two or more wires go to one connection they should be twisted together beforehand.

A wire attached under a washer should always be placed around the screw in a clockwise direction. Turning the screw or a nut on the screw then has the effect of drawing the wire in (Fig. 240).

Flexible wire extensions are best supported from a ceiling on insulated eyelets (Fig. 241).

In the case of a plaster ceiling, care should be taken to screw these into a lath or joist and not into plaster between laths (Fig. 242). The position of a lath can be found by probing the ceiling with a fine bradawl.

176. Joining lengths of flexible wire.

Soldered joints in flexible wire are seldom satisfactory; it is best to make use of insulated connections. These are made with one, two or three connections and cost from 1½d. to 4½d. each (Fig. 243).

Long lengths of flexible wire can be attached to a string stretched across the laboratory. If a porcelain connector has been used it should be relieved of any pull by forming a loop in the wire as shown (Fig. 244).

A flexible wire insulator made of porcelain and costing 1d., provides a very neat attachment for walls and ceilings (Fig. 245).

177. Electric light and power cable.

Best quality cable should be used. Cable sold without a maker's name sometimes has inferior insulation.

Cable can be bought from any electrician either by the yard or in long coils up to 100 yards in length.

The size of cable is specified in two ways. A cable of 1/18 size is made up of one strand of No. 18 wire of standard gauge. A No. 18 wire has a diameter of ·048 inches and will carry a current of 7·2 ampères without heating. This wire is often specified as 1/·048 wire.

A cable of the same current carrying capacity is 3/22 or 3/·028. This is more flexible than 1/18.

Size S.W G.	Size, diameter notative	Current Carrying Capacity (Institution of Elec. Engineers Standard)
3/20	3/·036	12·0 ampères
7/22	7/·028	17·0 ,,
7/20	7/·036	24·0 ,,
7/18	7/·048	34·0 ,,

Electric light branch circuits are usually wired with 1/18 or 3/22 wire.

The size of cable to be used for a power circuit is controlled by the maximum current to be taken.

178. Repairing fuses.

Before repairing fuses it is advisable to have some knowledge of wiring connections. The wiring of a typical electric light system is shown (Fig. 246).

If the supply is at 200 volts and each branch circuit has to carry a load of 1,000 watts the current in these branches will be 5 ampères and 1 /18 or 3 /22 cable can be used for the branches. It is customary to arrange the branch circuit fuses under a glass cover on a fuse board. Size 1 /18 wire will safely carry a current of 7·2 ampères, so a branch fuse that will melt with a current of 8–10 ampères will be a suitable one to use for the protection of the circuit. Fuse wire is made of tin or of copper coated with tin to protect the copper from corrosion.

It can be obtained in various sizes to fuse with different currents.

Useful fusing points are 5, 10, 15, 20, 25, and 30 ampères. If a 20 ampère fuse wire be required, and 10 ampère wire only be available, two strands of the latter can be used to make the equivalent of a 20 ampère wire.

For currents, above 15 ampères, tinned copper fuse wire is the best to use; it is not as thick as tin fuse wire of the same fusing point, so there is less molten metal to scatter about when it melts.

If fuse wire of the correct value has been put in the branch fuses the consumer's main fuse should not melt unless a short current takes place between the main fuse and the branch fuse board.

If the maximum load, with all branch circuits taken into consideration, be 2,000 watts, the current in the cable from the main to the branch fuse board will be 10 ampères on a 200 volt circuit and No. 7 /22 cable can be used and will be sufficiently protected by a 15–20 ampère consumer's main fuse.

If a consumer's main fuse has to be replaced it is advisable to inspect the data on the meter and note the maximum current that it has been designed for.

In the example given it might be 20 ampères and the electric supply company would probably protect it by placing a 20 ampère fuse wire in their fuse carrier and the consumer's main fuse should be arranged to go at 15 ampères, so that it will fuse in preference to the one belonging to the company that can only be unsealed and repaired by the latter's representative.

179. Some common causes of a fuse blowing.

An electrician often refers to the process of a fuse coming into action as blowing.

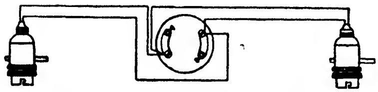


Fig 239. Method of connecting two lamps to one ceiling rose

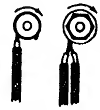


Fig. 240.

Fig. 241. Insulated eyelet with porcelain lining

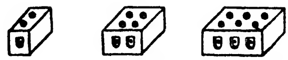


Fig. 243. Porcelain connectors

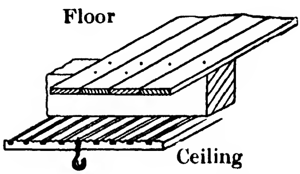


Fig. 242. Insulated eyelet should be screwed into a lathe or joist

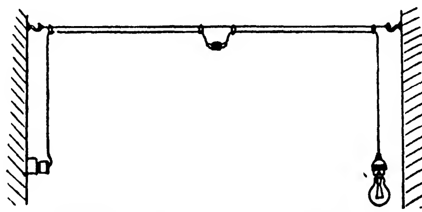


Fig. 244. How to join and support flexible wire

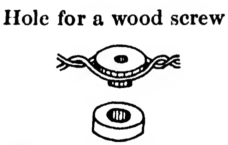


Fig. 245. A flexible wire insulator

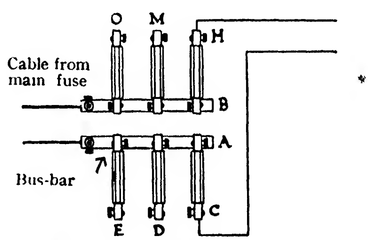
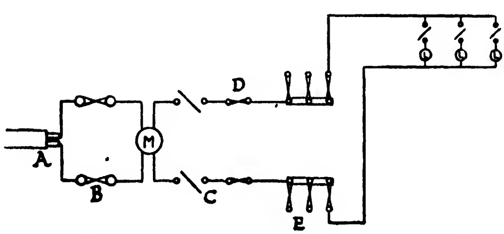


Fig. 247. Arrangement of fuses on a fuse board



A. Main cable
B. Company's main fuses
C. Consumer's main switch
D. Consumer's main fuses
E. Fuses on distribution, or branch fuse board
L. Lamp
M. Meter

Fig. 246. A typical electric light system. One distribution circuit only is shown

Common reasons for this are as follows:

(1) An attempt has been made to connect a piece of apparatus taking a larger current than the branch fuses can carry. A 10 ampère arc lamp or an electric heater connected to a lighting supply will sometimes cause a fuse to blow. Even a small arc lamp connected without a series resistance will have the same effect.

(2) Short circuits. These may be caused by incorrect connections or by the insulation of old connections wearing away. Flexible wire connected to plugs and portable electrical apparatus is very liable to suffer from frayed insulation, and should be inspected from time to time. Sticky insulating tape, to be bought at garages and electricians' shops, is often useful for binding round wire where chafing has or is likely to occur. Flexible wire, used for the connection of lamps suspended over the benches of a chemical laboratory, is very liable to suffer from corroded insulation just above the cord grips. The corrosion may extend to the wires. A failure of the light, with possibly a short circuit, is the consequence. For chemical laboratories it is best to use flexible wire heavily insulated with rubber without a cotton or silk covering and to use moulded Bakelite lamp holders and switch covers instead of metal ones.

(3) Overloaded fuse. A fuse, subject to a current very close to the fusing value is liable to get hot and slowly oxidise. This reduces its carrying capacity and after an hour or possibly months of service it will suddenly blow with no apparent reason.

180. Searching for a blown fuse.

If possible turn off the supply at the main switch, then pull out the fuses from their clips and examine them to find out which one has melted. It is best to do this, one by one and replace each one after inspection. Correct the cause of the fuse blowing, then fit a new wire of appropriate size.

Sometimes a fuse does not melt throughout its whole length and it becomes difficult to locate the faulty one by direct inspection. It is often helpful when examining a fuse wire to give it a slight sideways push with a small screw-driver. A rapid and certain method of searching for a blown fuse is to use a lamp in a holder provided with a foot or two of flexible wire. The ends of the wire are left bare (Fig. 248).

Fig. 247 represents a fuse board. Cable from the main fuse board

is connected to two metal bars, the bus-bars A and B. Branch circuits are connected to C and H, D and M, E and O.

To test the fuse between B and H, leave the main switch on, hold the flexible wire with the lamp attached, but keep the fingers well away from the bare ends. With the ends make a connection by touching the metal clip at H and some part of the bus-bar A.

If the lamp lights up the fuse BH is in order and the faulty fuse must be sought elsewhere. Fuse AC would be tested by connecting the lamp between C and B.

Each branch circuit is protected by two fuses. If one fuse blows the companion one usually blows as well. If possible always turn off the supply at the main before replacing a fuse unless the cause of its blowing has, without any doubt, been removed.

The failure of all the lights in a building may be caused by each of the branch circuits being used to full capacity, thus placing an abnormal load on the main fuses. A short circuit between branch wires will sometimes cause a main fuse to blow.

On an alternating current circuit it is quite easy, by listening to the meter, to distinguish between the failure of the company's supply and a failure due to a consumer's main fuse blowing.

If a hum can be heard the supply is on up to that point.

181. Extensions and modifications of an electrical supply.

Extra lamp-holders, sockets and switches are often required in a workshop or laboratory and armed with a little knowledge of wiring it is a simple matter to make modifications.

Sockets and lamp holders connected to a main supply are usually arranged in parallel and a typical text book diagram is shown (Fig. 249). This shows three lamps controlled by separate switches, a socket, and two lamps controlled by one switch.

A practical wiring diagram is very different to a text book diagram. It is advisable to avoid joints in cable. Fig. 249 shows joints at A, B, C, D, E, F, G, H, M and N. Joints in the cable are avoided by making two or more connections to the terminals of the various fittings. This is known as looping in.

Fig. 250 shows a wireman's method of making the necessary connections without a single cable joint. A practical wireman seldom bothers to make a diagram, since the necessity of keeping all lamps and sockets in parallel is easily adhered to by remembering three things.

(1) One cable from the distribution board must make a connection to every switch and socket.

(2) The other cable from the distribution board must make a connection to every lamp holder and socket.

(3) Each lamp holder and its respective switch must be connected between the terminals not already provided with a wire.

The wiring of an apparently complicated system of lamps and switches is reduced to a matter of great simplicity by following the above three rules.

182. Wiring systems.

Cable connections between fittings can be made with ordinary insulated cable held in place on walls and ceilings by means of porcelain cleats (Fig. 251).

Cable, known as cab tyre cable, is manufactured. This has a very thick covering of rubber that provides good electrical insulation and protection from mechanical injury. It can be attached directly to walls and ceilings by special clips.

Lead covered cable can be used or ordinary insulated cable can be protected by steel conduit.

183. Open cable system.

The open cable system, with insulated wire held in cleats, is very often adopted in engineering works and has the great advantage of cheapness with ease of erection and access. For teaching purposes a wiring system is not without interest, and cables that are visible are better than cables hidden away. When making cable connections the outer braided covering can be cut away with a sharp knife or a pair of scissors. Leave about $\frac{3}{4}''$ length of uninjured rubber insulation between the bare wire and the end of the braid (Fig. 252).

Take care that no strands of cotton are left sticking to the rubber. Cotton is slightly hygroscopic and stray strands provide leakage paths and reduce the insulation resistance.

When connecting cable to fittings make quite certain that no bare wire is left projecting outside the porcelain insulation. Multiple wire cable such as 3/22 should be twisted after cutting to keep the strands together. After making a connection depending on a binding screw give the cable a slight pull to test the security of the connection. A loose fit may give rise to arcing with consequent heating of the fitting.

When a connection in a fitting is common to two or more cable ends twist the ends together before pushing them into the connection (Fig. 253).

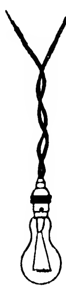


Fig. 248. A test lamp

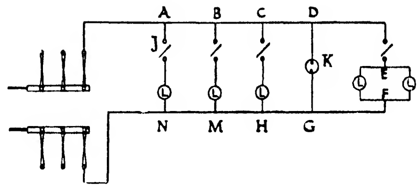


Fig. 249. A typical text book diagram of an electric light circuit. J. Switch; K. Socket; L. Lamp

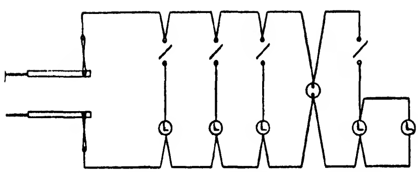


Fig. 250. How connections are made in actual practice. Joints in wires are avoided if possible

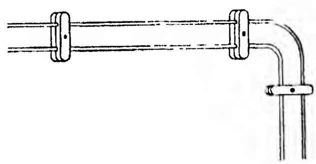


Fig. 251.

Fig. 252.
A. Bare wire
B. Rubber
C. Braid

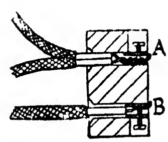


Fig. 253. Method of connecting insulated cable to a fitting
A. Ends twisted together
B. End turned over

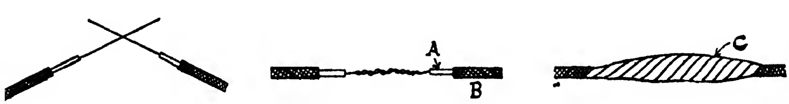


Fig. 254. Method of joining wires
A. Rubber insulation
B. Braid covering
C. Joint is soldered, insulated with rubber tape and covered with sticky tape

Joints in cable can be made by first crossing the bared ends of the wire and then twisting them one on the other as shown (Fig. 254).

Avoid projecting sharp ends. Solder the joints, using a little Fluxite or powdered resin as flux (see Sec. **135**). Treat each joint with rubber tyre solution then wind rubber tape over the wire. Keep the tape taut during the winding. The tape should overlap the rubber insulation of the wire. Finish the insulation of the joint by winding ordinary sticky insulating tape over the rubber tape. Sometimes it is a little difficult to keep the rubber tape in position during the winding of the sticky tape.

The sticky tape should overlap the braid insulation of the cable, but the diameter of the finished joint should not be very much more than the original diameter of the cable.

Porcelain cleats can be attached to walls and ceilings with ordinary round headed wood screws. Brick and concrete walls may have to be plugged before this can be done (see Sec. **201**).

184. Lead covered cable system.

Very neat, almost invisible wiring can be carried out with lead covered cable. It is often used for the surface wiring of churches. The lead sheathing may contain one to three wires and can be obtained in different sizes according to the current that has to be carried. The cable is sold coiled up on a small drum and care has to be taken when unwinding it to avoid kinks. Bends and general irregularities can be removed by drawing the cable between the fingers and thumb. It is attached to skirting boards, door posts and walls by means of special clips sold by the makers. These clips are made of metal that has little or no electrolytic action with the lead. An improvised clip can be made out of a portion of lead sheathing hammered flat. The clips are fixed by means of brass screws or brass nails. Joints and branch circuits are provided for by the use of junction boxes, these contain porcelain insulated connections and the metal cover and base of the box ensure electrical continuity of the lead sheathing.

When switches are attached to wooden baseboards and not to special metal bases it is necessary to connect the sheathing of any cables that enter the board by means of small clips or clips and a length of copper wire (Fig. 255).

Lead covered cable is easily cut in half by means of a hack-saw, the lead sheathing at one end is removed by making a shallow knife cut in the lead, then bending the end backwards and forwards. The lead fractures at the knife cut. the sheathing can

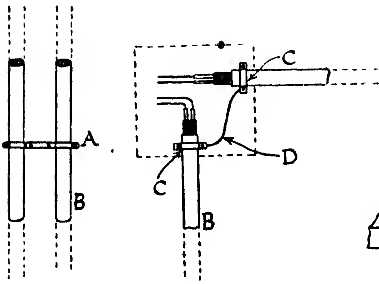


Fig. 255.

A. Continuity clip C. Clips
B. Lead covered cable D. Copper wire

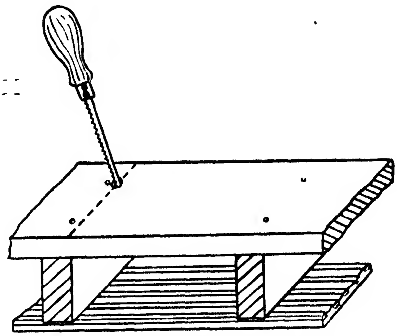


Fig. 257. Cutting a floor board with a keyhole saw

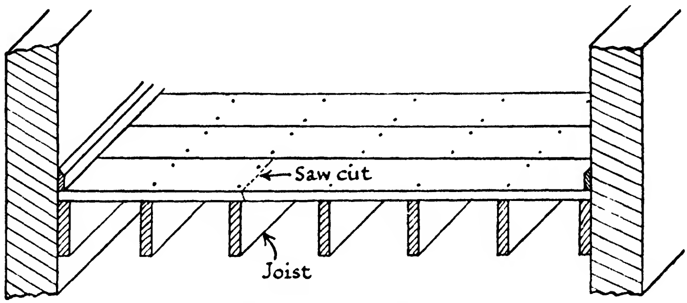


Fig. 256. Removing floor board

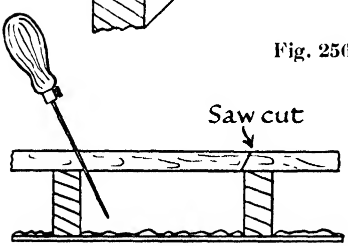


Fig. 258 Removing a short length of floor board

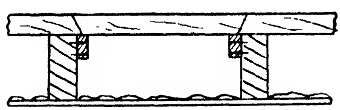


Fig. 259. Method of replacing a floor board

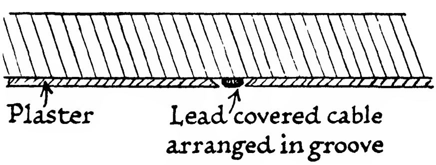


Fig. 260.

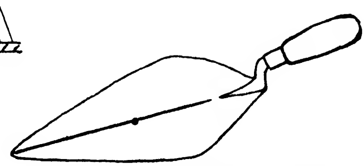


Fig. 261. A plasterer's trowel

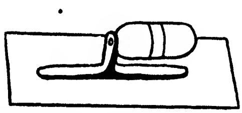


Fig 262. Iron smoothing tool

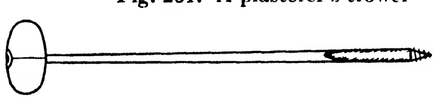


Fig. 263. A bell-hanger's gimlet

then be pulled off without any injury being done to the cable inside.

185. Removing floor boards.

Sometimes, when laying cable, it becomes necessary to remove a floor board. A whole length of floor board can be removed by punching down the nails that attach it to the joists. Use a nail punch and a heavy hammer. Sometimes a floor board goes under the skirting boards at both ends and even supposing the holding nails are punched down it remains impossible to prise it up (Fig. 256). In such a case the board must be cut with a keyhole saw. By inspection of the nails and by examination of the cracks between the boards locate the position of a joist. Bore a $\frac{3}{8}''$ diameter hole through the board close to the joist, insert a keyhole saw and cut the board across. Use the saw inclined at an angle of 45° with the top of the joist. If the nails have been punched down the board can now be taken up (Fig. 257). A small length of board can be taken up by making two saw cuts (Fig. 258).

When a board has to be replaced, nail stout strips of wood to the joists at each of the saw cuts to form a ledge at each place for the board to rest on (Fig. 259).

When boards have been taken up for the laying of cable it is best, when replacing to secure them with brass screws. Brass screws do not rust and it is easy, if necessary, to take the boards up again at some future date.

Lead covered cable can be hidden away in grooves cut with a cold chisel and hammer in the face of plaster covered walls (Fig. 260).

Repairs to plaster are effected with Keene's cement, this is a mixture of plaster of Paris and alum and can be bought at any oil shop or from a builder. With the help of a cold chisel undercut the old plaster to provide a key for the new (Fig. 260). Mix the cement with water to make a wet mass. Take a painter's brush and make the old plaster in the cut thoroughly wet. Apply cement to the cut and gradually fill it in. It is most important to keep on wetting the old plaster during the filling in process or it will absorb too much moisture from the new cement to yield a good repair.

A plasterer's trowel as shown in fig. 261 is a useful tool for applying the cement; the surface can be finally smoothed down with a small piece of board or a proper iron smoothing tool (Fig. 262).

When cable has to be taken from one room, up a wall to the space below the floor of the room above, it will be found that a

bell-hanger's gimlet 30″ long is a most useful tool for making a pilot hole through the plaster and so into a space between joists (Figs. 263 and 264).

Cable can be taken across joists by cutting a small groove in each one just deep enough to allow the cable to sink flush with the top surface of the joist (Fig. 265).

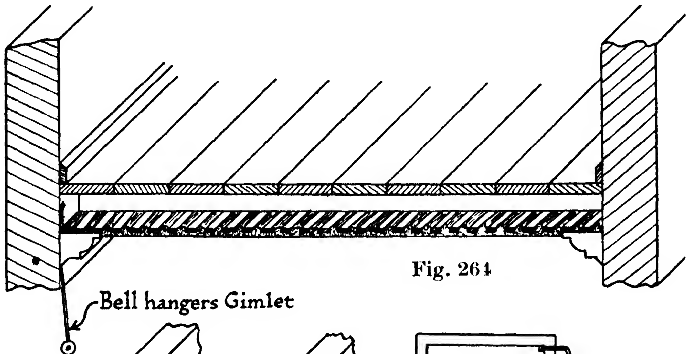


Fig. 264

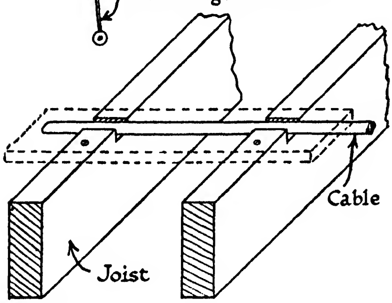


Fig. 265. Carrying a cable across joists

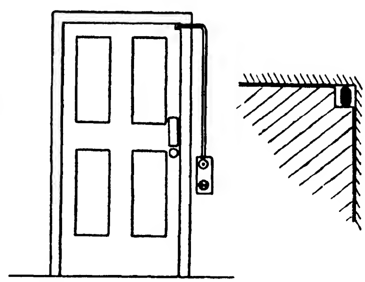


Fig. 266. Method of cutting a door to pass a cable through

The groove is easily formed by making two shallow vertical cuts with a tenon saw and by removing the wood between the cuts with the help of a mallet and wood chisel. Do not unduly weaken the joists by deep saw cuts and take care, when replacing boards, not to drive screws into the cable, for this reason it is best to keep the cable under the centre of the boards.

Doors set in brick or concrete walls sometimes present difficulties. Cable can be taken past them from one room into another by cutting away a small rectangular portion of wood from the top corner of the door. This allows it to be shut without crushing the lead cable (Fig. 266).

186. Conduit wiring system.

In this system ordinary insulated cable is encased in steel tube,

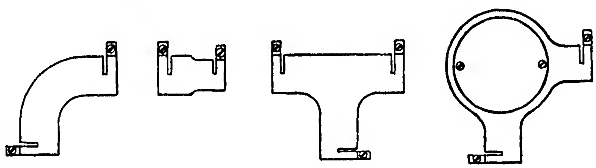
this may be screwed together like water pipes or arranged with screw grip fittings. The latter system only will be described here.

Conduit is enamelled and in two qualities, one with a joint closed, but not brazed and the other with a brazed joint that makes it quite waterproof.

For ordinary interior work the closed joint conduit is quite suitable, but for places where the conduit is buried in plaster the slightly more expensive brazed conduit should be used. It is sold in lengths of about 13′ and in diameters from $\frac{1}{2}''$ to $1''$. Conduit of $\frac{1}{2}''$ and $\frac{5}{8}''$ diam. is suitable for most work; if more than three wires or thick power cable has to be threaded through, it is necessary to use larger diameter conduit. $\frac{3}{4}''$ diam. conduit will take several lengths of 7/22 cable.

Reducing sockets make it possible to connect one diameter conduit to another.

Tees and elbows can be obtained in the different sizes and it is often a help when threading through to use the type with inspection covers (Fig. 267).



Elbow Reducer T piece T piece with inspection cover

Fig. 267. Conduit fittings

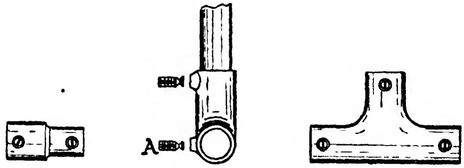
Conduit can be cut with a hack-saw but a more satisfactory method is to use a triangular file and break it by first filing a nick all round, then bending it over the end of a table.

The sharp edge left at the end of a section of conduit after cutting must be removed by filing. A round or half round file is useful for doing the inside edge.

Before fitting a length of conduit into an elbow or tee it should be given a few rough strokes with a file to a distance of $\frac{1}{2}''$ from each end. This removes some of the enamel and makes certain that good electrical continuity is obtained. It is only a matter of a few moments to treat the inside socketing surface of each fitting in the same say.

In the Simplex conduit system the fittings used are provided with special screws that cut through the enamel coating of the conduit and so secure good electrical continuity (Fig. 268), making filing unnecessary. The manufacturers are: Simplex Conduits Ltd., Garrison Lane, Birmingham.

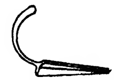
Conduit can be fixed to walls with the help of crampets or saddles (Fig. 269), and it may be necessary to plug the walls.



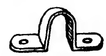
Reducing socket

Fig. 268. Simplex conduit fittings. A. These small screws hold the fittings together and ensure electrical continuity.

By courtesy of Simplex Electric Co., Ltd.



A crampet



A saddle

Fig. 269

The threading of the cable through the conduit is most readily done before the latter is put in place. Conduit provided with inspection tees and elbows is easily threaded after erection, sometimes it is a help to push a stiff wire through the conduit, then attach the former to the cable and use it as a pull-through.

The screw-grip of all fittings should be well tightened to ensure continuity. The use of red and of black cable simplifies the sorting out of connections.

187. To test the electrical continuity of lead cable and conduit systems.

The sheathing of lead cable and the steel tube of conduit systems should be permanently connected at some point by means of earthing clips and a wire to the ground. This can be effected by joining the earthing wire to a water-pipe. Never connect to a gas-pipe and always keep lead covered cable and conduit out of contact with gas pipes.

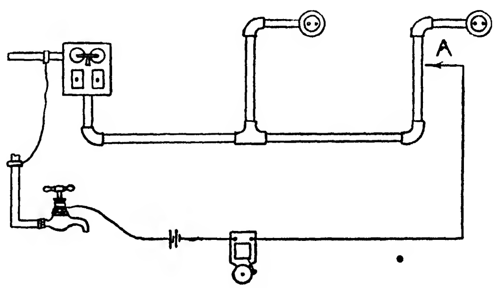


Fig. 270. A continuity test

A continuity test can be made with the help of an electric bell (Fig. 270). It should be possible to make contact with the free end A of the bell wire at any point on a cleaned surface of the lead sheath or steel tube and get the bell to ring.

188. Electrical connections near water taps.

It is never wise and contrary to the wiring regulations of many supply companies to arrange metal covered switches close to water taps, leakage to the metal cover and favourable conditions for a ground connection might give rise to an electric shock.

189. General wiring test.

Before the wires of a new and complex system are connected to the main they should be tested by joining them on to a battery and providing an electric bell with a length of flex and an adapter or plug that can be inserted in lamp holders or sockets. The correct wiring of switches can be tested by listening for the bell when they are turned on.

190. Insulation test.

Most electrical supply companies insist on making an insulation test of a new wiring system before giving a supply. One connection from a megohmeter is made to the ground and another to the wire of the cable used in the installation. The resistance between the two is measured. If care has been taken to avoid injury to the insulation and stray strands of cotton have been removed from the bared rubber (see Sec. **183**) it is seldom difficult to obtain a satisfactory test.

191. Attaching fittings.

Ceiling roses and switches are usually mounted on wooden blocks. Round and rectangular blocks already hollowed out at the back can be obtained.

Connections between flexible wire and cable can be made through a ceiling rose or by means of a porcelain connection hidden away inside the block (Figs. 271 and 272, page 154).

If lead-covered cable or conduit leading to a switch has been buried in a groove cut in a wall the switch block need not be cut. If the cable or conduit has been arranged on the surface of the wall it is necessary to cut out a portion of the block to allow it to fit flush (Fig. 273, page 154).

To fix switches on a block, first take off the covers then arrange the switches symmetrically on the block and prick through the positions of the terminal connections and holes for the attaching wood screws. Bore holes about $\frac{3}{8}''$ diam. for the cable to come through the block below the terminals and drill small starting holes for the wood screws. No. 8 size wood screws are suitable for

most fittings. The length to use depends on the fitting and the thickness of the baseboard. The next thing is to arrange for fixing the block to the wall. A circular block for a single switch can be attached with one central screw, a rectangular block requires two. Drill and countersink holes for the attaching screws and arrange for them to come under the switches where they will not show. Prick through the positions of the screw holes on to the wall and if necessary plug it.

Thread the cable through the holes made in the block then attach the latter to the wall. Pull out several inches of cable, connect to the switches, then push back the excess cable, it may be useful to have spare at some future date.

Screw the switches on to the block, tighten the attaching screws until the switches become firm, do not tighten too much or the porcelain bases may be cracked.

Any interconnection between switches, required for looping in (see Sec. **181**), should be provided for by means of a short length of cable put in position before the block is attached to the wall.

192. Two-way switches.

When a lantern is used it is often convenient if it is possible to switch off the lights from the entrance door or from the lecture table.

This can be done by the use of two-way switches. They cost about 1 /6 more than ordinary switches and contain three connections (Fig. 274).

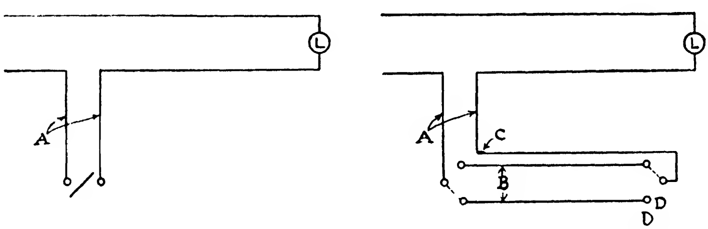


Fig. 275. Connections for installation of two-way switches as a substitute for an old one-way switch

A. Old wires B. New wires C. Soldered and insulated joint D. New switch position

When a one-way switch is removed and replaced by a two-way one it is necessary to make a joint and provide for an extension of one of the original wires leading down to the switch (Fig. 275).

This joint can be soldered (see Sec. **183**), or made with the help of a porcelain connector (Fig. 243) hidden away under the switch block.

Three wires have to go to the distant switch. Lead covered cable can be obtained containing three wires.

193. Outdoor wiring.

Bare copper, telephone or bell wires can be attached to insulators as shown (Fig. 276). Porcelain drawer knobs make good insulators (Fig. 277).

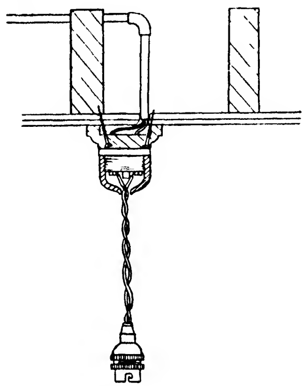


Fig. 271. A ceiling rose connection

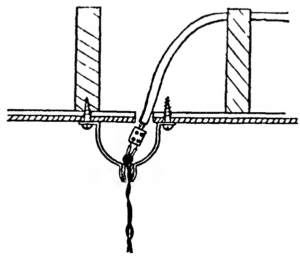


Fig. 272. Connection between cable and flexible wire made with a porcelain connector

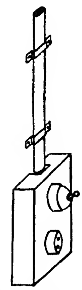


Fig. 273. Method of cutting a wooden block to allow lead covered cable or conduit to pass into it

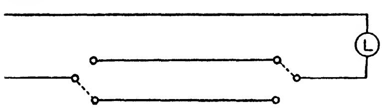


Fig. 274. Connections between two two-way switches (shown in off position)

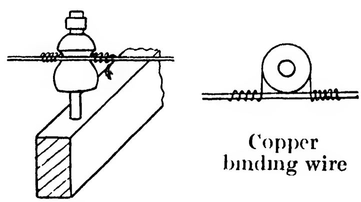


Fig. 276. Method of attaching bare copper wire or insulated cable to porcelain insulators

Fig. 277. A porcelain door knob can be used as an insulator

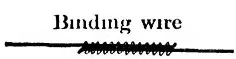


Fig. 278. A telegraph linesman's or Britannia joint. Joint is soldered solid

All joints in bare wire should be soldered. The telegraph linesman's joint, a very strong one, is shown (Fig. 278).

Connections for electric light and power can be made out of doors from one building to another by means of lead covered cable passed underground through screwed iron pipe, or by attaching it to walls. Use an unbroken length of cable, avoid joints.

Another method is to use well insulated cable and attach it with binding wires to porcelain insulators. Special insulated wire can be obtained for outside work. It has a protective coating of red lead-oxide paint.

Old bottle tops used as shown in Fig. 279 make good insulators; they can be cut off with the help of an iron ring made out of $\frac{3}{8}''$ to $\frac{1}{2}''$ diameter iron rod. The ring is made red hot in a fire and placed over the bottle. It is kept in position for a few seconds, taken off and the bottle is then plunged into cold water. The top will usually crack off under this treatment (Fig. 280).

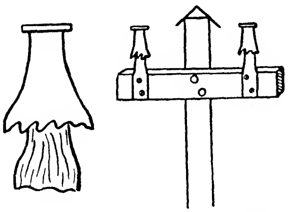


Fig. 279. Bottle top insulators

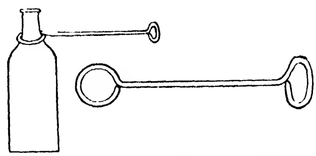


Fig. 280 Iron ring used for cutting glass bottles

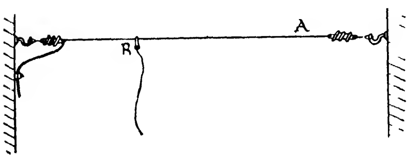
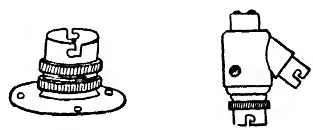


Fig. 281. Overhead connection for a low voltage supply. One wire only is shown but two are necessary
A. Bare copper wire B. Crocodile clip



Batten type Two-way push bar
Fig. 282.

194. Low voltage direct current laboratory supply.

A convenient method of supplying benches with a D.C. supply from a generator or accumulators is to arrange bare overhead copper wire across or along the length of the laboratory and to make connections with crocodile clips to be obtained from a wireless supply shop (Fig. 281).

195. Useful fittings.

Some useful laboratory electrical fittings are shown in fig. 282.

CHAPTER IX

MISCELLANEOUS PROCESSES

THE CUTTING, DRILLING AND GRINDING OF GLASS

196. Cutting sheet glass.

THE cutting of a sheet of glass, as carried out by the expert, appears to be a very simple matter, but the beginner is seldom very successful. It is interesting to examine and compare under a microscope the scratch made by an expert and that of an amateur.

The expert produces a small, almost invisible, line that gives rise to diffraction effects, the scratch made by an amateur is usually white, has fractured edges and does not show special optical effects.

Fig. 283. Glazier's diamond

The expert's scratch will develop without any difficulty, into a clean cut fracture.

The usual tool for cutting glass is a glazier's diamond (Fig. 283). The small black diamond fragment is mounted in a holder. A diamond for cutting ordinary window glass costs about 10/–. Plate glass is usually cut with a larger diamond than that used for thin window glass. It is more expensive and is seldom required in a laboratory.

Fig. 284. Steel wheel glass cutter

Glaziers' diamonds vary in quality and it is advisable to purchase one mounted by a well-known firm such as Sharratt & Newth. In recent years steel wheel glass cutters have been much improved, they cost about 1/– each and quite apart from their cheapness are used by many workmen in preference to a diamond (Fig. 284).

The sheet of glass to be cut should be laid on a firm, flat surface.

A drawing board is very suitable. A fairly thick straight edge such as a boxwood rule, is then held firmly on the glass about $\frac{1}{16}$" away from where the cut is desired; this makes allowance for the distance of the diamond or steel wheel from the edge of its holder.

The handle of the holder is then held between the thumb and second finger of the right hand with the forefinger on top to steady it. The angle at which a diamond holder is held should be such that the bottom edge is parallel to the glass sheet as shown in fig. 285. The scratch should be started at the far edge and made with steady pressure in one continuous stroke to the near edge. Most amateur glass cutters press far too hard and so fail to produce the necessary fine, almost invisible scratch.

It is a great help to dip the diamond or steel wheel into turpentine before using it. If this precaution be taken the amateur can, at the first attempt at glass cutting, produce the expert's type of scratch. This is a method well known to a certain section of the glass trade and makes a steel wheel cutter as effective as a diamond.

Never go over a scratch a second time, it must be made in a single, continuous movement.

If the sheet of glass be thin, it can be snapped apart by gripping it on both sides and at one end of the scratch and by giving a sharp bend and pull to the glass at the same time (Fig. 286).

Some grades of glass are more difficult to cut than others and may require tapping, just below the scratch on the under surface before a fracture can be started and the glass separated by the method already described.

The sheet glass used for photographic plates is very easy to cut. Old negatives can be obtained from a professional photographer and the emulsion is readily cleaned off by treatment with boiling water and washing soda.

Ruby glass, as used in photographic lamps, has a hard surface coating of coloured glass on one side only. When red glass has to be cut the scratch should be made on the soft, non-coated side.

Ground and silvered glass should be cut on the plain side.

If an imperfect scratch has been made it sometimes happens that small jagged projections are left after cutting. These can be removed with the help of a pair of parallel jaw pliers, or by the aid of notches on the side of a steel wheel type of cutter (Fig. 287). Guard against splinters by doing the work at arm's length and preferably over a waste box.

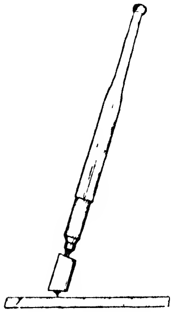


Fig. 285. Correct angle to hold cutter Face of tool must be kept parallel to glass when cutting

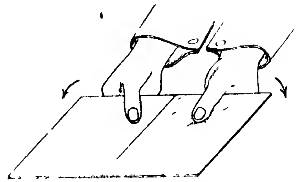


Fig. 286 Snapping apart sheet glass

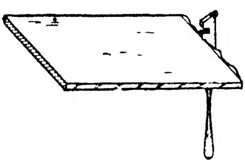


Fig. 287. Removing jagged edges by means of notches on side of a steel wheel cutter

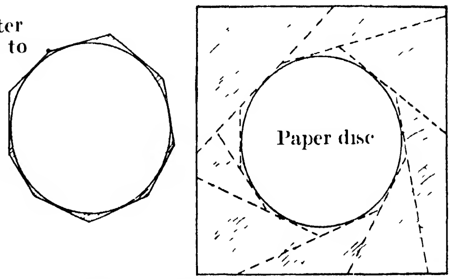


Fig. 288. Cutting a circle in glass

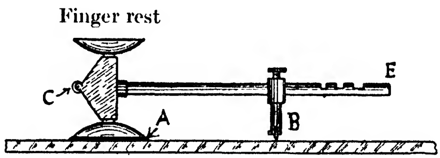


Fig. 290. Circle cutter. A. Rubber disc; B. Steel wheel cutter. *By courtesy of T. E. Riley*

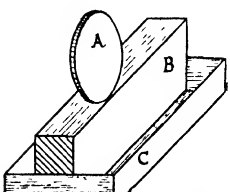


Fig. 289.

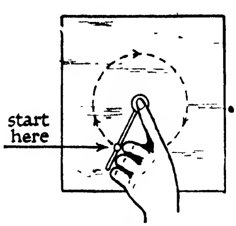


Fig. 291.
Method of using circle cutter

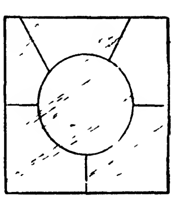


Fig. 292.
Diagram showing radial scratches

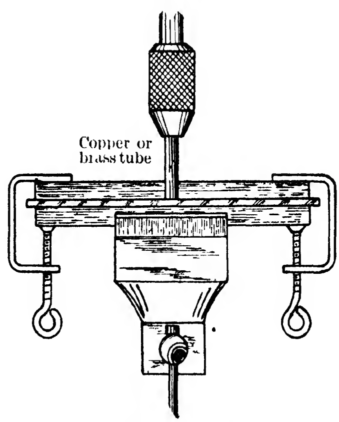


Fig. 293. Drilling sheet glass

197. Cutting circles.

It occasionally happens that an instrument with a circular front requires a new piece of glass. This can be prepared by pasting a disc of writing paper of the required diameter on the glass to be cut. With the help of a glass cutter, guided by a ruler, make a series of scratches tangential to the paper disc, and so remove first one and then another portion of the glass surrounding the disc (Fig. 288).

This method leaves the glass with a series of sharp corners, these are easily ground off by rubbing the edge on the side of a carborundum oil stone. During the grinding constantly dip the glass into turpentine and keep the stone well supplied with the same liquid. Turpentine has the peculiar effect of preventing the glass from splintering and enables a good ground edge to be obtained (Fig. 289).

It is best to use the side of the stone, since the grinding of glass on it tends to produce a grooved surface.

The grinding of the corners does not take more than a few minutes, and when completed the paper disc can be soaked off in hot water.

198. The use of a circle cutter.

At a cost of 1/6 a special tool[1] can be purchased for cutting circles up to 8″ in diameter (Fig. 290).

Start with the cutting wheel in a position below the steadying finger of the left hand as shown (Fig. 291). Apply pressure to the cutting wheel and with continuous even motion describe a circle.

Turpentine is an aid to forming the correct type of scratch.

Pick up the glass and tap it on the under surface below the scratch mark. The end E (Fig. 290) of the circle cutter makes a good tapping tool. As a rule, gentle tapping causes the scratch to develop into a circular crack, but the process can, if necessary, be assisted by applying slight pressure with the thumbs, one being placed on each side of the crack, but on the under surface of the glass. The thumbs should be moved along as the crack spreads round.

A complete circular crack having been formed, the next thing is to free the disc from its surroundings.

Place the glass on a flat surface and using the wheel C (Fig. 290) of the tool as an ordinary glass cutter make a series of scratches as shown (Fig. 292).

[1] Stocked by Messrs. Buck and Ryan, 310–312, Euston Road, London, N.W.1.

Pick the glass up and give the superfluous portions a series of sharp taps below the scratches. The scratches will develop into cracks, but these are unable to spread beyond the circular one.

By a process of slight combined bending and pulling, the unwanted glass can be very easily removed thus leaving a well-formed circular disc.

199. Drilling sheet glass.

Some pieces of apparatus require the drilling of holes in sheet glass. This can be most successfully carried out as follows.

Select a fairly thin copper or brass tube of the same external diameter as the hole required. A tube 2″ long is convenient. File one end of the tube flat and grip the other end in the chuck of a bench drilling machine or failing this use a hand drill. If the tube be too large to go into the chuck, drive a wooden peg into the end and taper the peg sufficiently to fit into the chuck.

If a drilling machine be available the sheet of glass should be placed on a block of wood arranged on the table of the machine. A few nails driven into the wood will prevent the glass moving sideways during the start of the drilling process.

Make up a mixture of carborundum powder and turpentine and place a heap of well moistened powder on the glass where the hole has to be drilled (medium No. 100 powder is suitable).

Turn the handle of the drill and bring the tube down on to the glass. The powder is carried round by the tube and the hard, sharp edged grains quickly cut into and through the glass. The drill can be turned quickly, but the pressure of the tube on the glass should be fairly light. Keep the tube well supplied with grinding mixture and do not stint the turpentine or the tube will get hot and cracks will start. Every fifteen seconds or so, raise the tube and push grinding mixture into the circular groove that forms in the glass; in this way the flat, under surface of the tube is kept well supplied with abrasive.

When half through the glass, turn it over and continue to drill from the other side. This avoids splintering one edge.

If a hand drill be used some kind of guide for the tube is necessary. This can take the form of a wooden block with a suitable hole in it to accommodate the tube. The block can be clamped on top of the glass plate and drilling is then carried out as before (Fig. 293).

By the method described it is possible to drill a $\frac{1}{4}$″ diameter hole through a sheet of window glass in about 10 minutes. Plate glass is as easily drilled as thin glass, but of course takes longer to

penetrate. A cylindrical pellet of glass is formed by the cutting tool.

200. Cutting glass rod and tube.

Glass tubing and rod up to $\frac{1}{2}''$ in diameter can be cut by nicking one side with a triangular file and then smartly bending and pulling each side of the nick.

Large diameter tubes require a different procedure. Glass cells for use in a horizontal projection lantern can be made by cutting off a narrow ring of large diameter glass tubing and cementing it on to a plate of glass. To cut such a ring, first gum a piece of paper around the tube leaving an amount of tube projecting equal to the depth of the cell. Make a scratch with a glass cutter, or file a nick around the tube using the edge of the paper as a guide. The ring can be neatly removed by means of an electrically heated length of Nichrome resistance-wire stretched between two supports (Fig. 294).

The current required to make the wire red hot can be taken from the mains by placing a suitable resistance, such as an arc lamp resistance, in series with it. Another method is to use a step-down transformer giving 25 volts.

The tube to be cut is held against the red hot wire with the wire pressing against the tube where the scratch or nick has been made. A crack is formed and can be made to follow round by slowly rotating the tube keeping the latter all the time in contact with the wire.

Any irregularity in the end face of the cut off ring of glass can be removed by rubbing the ring up and down on a flat carborundum oil stone well lubricated with turpentine.

To form a cell the ring has to be cemented to a plate of glass. A lantern slide cover glass is very suitable for this.

Place carborundum powder and turpentine on the plate, put the ring in position and rotate it clockwise and anti-clockwise. This has the effect of forming a rough place on the glass plate corresponding to the cross section of the ring.

Wash away the abrasive and cement the ring and plate together with Durofix cement, or a concentrated solution of shellac dissolved in methylated spirit.

During the drying of the cement the ring should have a weight placed on it to keep it pressed down on the plate.

201. Plugging walls.

The tools required for plugging a wall consist of a hammer and a special steel drill sometimes known as a plugging chisel or

jumper. The work consists of making a suitable hole in the brick or cement of a wall and hammering into this a wooden plug for the reception of a screw used in the attachment of a fitting to the wall. A good form of drill is shown (Fig. 295).

The method of using it is as follows.

Hold the fitting to be attached against the wall and mark the position of the screw holes. Take the fitting away. Put the point of the drill on the mark and give the other end heavy blows with a hammer. The peculiar shape of the tool enables it to penetrate hard material. After every two or three blows, give the drill a slight turn, this causes it to form a hole of circular cross section and prevents the drill from getting jammed. Take great care to keep the tool square to the wall (Fig. 296). The depth of the drill hole depends on the weight of the fitting to be attached and the size of the screws to be used. From one to two inches is a usual depth. If the hole has been made 2″ deep, cut a piece of wood about $1\frac{3}{4}$″ long, of roughly square section and large enough to be a tight fit when hammered into the hole. A certain amount of judgment must be used when selecting and shaping the wooden plug (Fig. 297). Hammer the plug into the hole until it becomes tightly fixed and the near end has come flush with the surface of the wall. Very neat wall plugs can be made of dowel rod.

A piece of $\frac{1}{2}$″ diameter dowel rod forms a good plug for a $\frac{3}{8}$″ diam. hole. One end can be pared down with a chisel, so that it is an easy matter to start driving it into the hole (Fig. 297).

Another form of plugging chisel is shown (Fig. 298). This is an effective tool. The cutting end is hollow and provided with hard steel edges. A useful size is the $\frac{3}{8}$″ tool costing about 1 /5.

For very neat wall plugging the Rawlplug system is useful.

A special small size jumper is used to make a hole for the insertion of a Rawlplug. This is a tube of stiffened fibre which automatically expands when a screw is driven into it (Fig. 299).

The successful use of a Rawlplug depends on the formation of a good hole. The jumper must be kept square to the wall and frequently rotated between hammer blows. The No. 8 size of jumper designed for hard material is suitable for general work and No. 8 Rawlplugs suitable for size 8 wood screws can be bought in boxes of assorted lengths.

202. Painting and enamelling apparatus.

Baseboards and other wooden parts of apparatus can be stained, oiled or polished to obtain a good finish.

Before treating wooden parts it is always best to remove metal

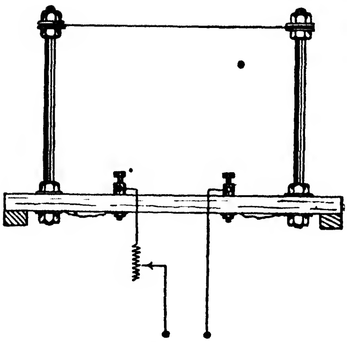


Fig. 294
An electrically heated wire

Fig. 295. A drill for plugging walls

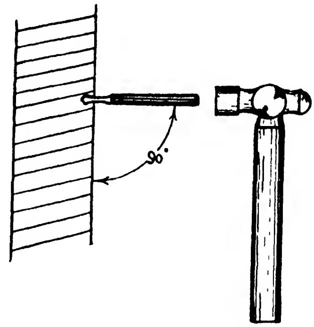


Fig. 296. Plugging a wall

Rectangular plug   Plug made from a dowel rod
Fig. 297

Fig. 298. A hollow plugging chisel

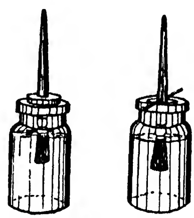


Fig. 300   Fig. 301
Brush suspended in lacquer solution

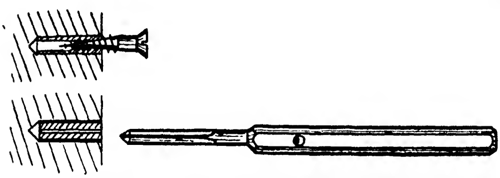


Fig. 299. Rawlplug drill
By courtesy of Rawlplug Co., Ltd.

fittings, so that all parts of the wood can be treated and the fittings do not get marked.

Wood such as oak with a distinct grain is best left unstained, it can be well smoothed with glass paper, then rubbed over with boiled linseed oil. Boiled oil can be purchased from any colour merchant.

Light-coloured woods can be stained with dye to prevent them showing finger marks.

S. C. Johnson & Son, Ltd., West Drayton, Middlesex, England, make a wide range of wood dyes. Green Solignum gives an effective finish to benches and stools.

Wood used in the construction of optical apparatus is best made black. An excellent dead black is Roscoe cylinder black

manufactured by Owen Bros. & Co., Ltd., Hull. It is sold in small tins at Halford cycle shops and has remarkable covering power. It is heat proof, dries in twelve hours and makes an excellent finish to iron, tin plate or brass used in the construction of optical lanterns.

Aluminium paint can be used on wood or metal. Some brands of aluminium paint are far from satisfactory. Good quality aluminium paint is prepared with very fine particles of metal. The size of the particles has an effect on the covering power of the paint and the final finish.

'Slick' brand and Blundell's and Berger's aluminium paint can be recommended. Aluminium paint gives a good finish to retort-stands, pipes and iron work in general. One coat will cover all imperfections of the surface; it is cheap, easy to apply and soon dries.

Brass and other metal work used in the construction of apparatus can be preserved from tarnish by giving it a coat of celluloid dissolved in amyl acetate.

Scraps of celluloid can be obtained from a garage; it is used for the side windows of touring cars. Old celluloid protractors and set squares can also be used.

Amyl acetate is stocked by most chemists, it is a ready solvent of celluloid. The solution used should be diluted to a consistency a little less fluid than that of water.

The metal to be coated should be polished with fine glass paper followed by rubbing with a clean cloth; avoid grease and finger marks. The solution should be applied with a wide, soft camel-hair brush. Work the brush in even sweeps and do not go over the same place twice.

After use the brush should be washed out in amyl acetate or passed through a hole in the cork, so that it remains suspended in the solution (Fig. 300). Small parts can be hung on wires to dry, or supported on upturned drawing pins. This transparent celluloid lacquer dries hard in a few hours. It can be bought ready made under various trade names.

Robbialac enamel is useful for metal and woodwork, it can be obtained at most garages and paint shops. Bright colours look out of place when associated with apparatus. Panhard red, Sheffield grey and Singer grey are suitable colours in the Robbialac range.

Paint and enamel brushes that are not likely to be used again for some time should be well worked out on a piece of wood, rinsed in turpentine and washed clean with soap and hot water. If the brushes are in constant use it is not always convenient to

do this; in such a case they can be stored in a tin or jam pot containing water or turpentine to prevent the access of air to the paint between the bristles. Provision should be made to keep the bristles away from the bottom of the pot where they get contaminated with paint residues and bent out of shape by the weight of the handle. This is easily done by passing a long nail through a hole drilled in the handle (Fig. 301). A brush that has been stored in water should be wiped before use and it is advisable to keep brushes used for aluminium separate from those used for other paints. The fine particles of aluminium are liable to contaminate and spoil the appearance of other paints.

203. Wood polishing.

A simple method of giving an excellent finish to woodwork is to glass-paper it to a smooth surface, and then rub it over with boiled linseed oil. Allow the oil to soak in for an hour, or better let it remain overnight, then polish the surface with a solution of 1 part of flake shellac dissolved in 2 parts of methylated spirit. Make a pad formed of cotton wool wrapped in a piece of linen, pour some solution on to the wool, wrap it up in the linen and apply the pad to the oiled wood with a gentle circular motion. A polished surface is produced almost at once. This method is particularly effective when applied to mahogany.

204. The use of cardboard.

Thick brown cardboard, known in the trade as strawboard, and stocked by most office stationers, can be used for the making of many objects such as loud speaker horns, boxes, store trays and folding screens for micro projection work. It is a convenient and cheap substitute for wood and only a few simple tools are required to make use of it.

Strawboard is usually sold in sheets measuring $25'' \times 30''$. The thickness is regulated by the weight. A 4lb. sheet, measuring $25'' \times 30''$ has a thickness of approximately $\frac{3}{32}''$. 4lb. strawboard is a useful grade for general work.

The strawboard is marked out in pencil and cut with a sharp mount cutter's knife (Fig. 302), guided by a steel rule. Special steel rules can be purchased, but are not essential (Fig. 303).

Fig. 302. Mount cutter's knife

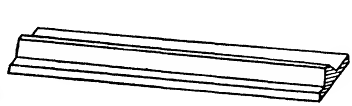


Fig. 303
Steel rule with finger guard

During cutting the strawboard should be placed on an old drawing board or other flat piece of wood, and it is usually necessary to go along the guide line several times before a complete cut can be made. It is well to keep an oil stone near at hand for sharpening the knife.

For fastening the strawboard together the writers have found no better glue than Higgins' Vegetable Glue[1]; it is sold in tins by most high class office stationers.

Once the tin has been opened it is well to turn out the contents into a glass or earthenware pot with a non-rusting cover. The glue, a thick white paste, is ready for use and is applied with a stiff brush. A portion can, for ease of working, be put on a saucer and diluted with water to thin it down.

A good flour paste can be made from ¼lb. of flour and ½oz. of powdered alum mixed with cold water to form a thin paste. When all lumps have been smoothed out with a stick, add one pint of cold water and heat in a saucepan with constant stirring. Boil for five minutes, but continue the stirring. Finally add seven drops of oil of cloves and seven of turpentine to serve as a preservative. When cold the paste is ready for use after stirring with a stick. This recipe for making paste is well known to bookbinders.

Strawboard can be fastened together at the corners by glueing on strips of blind material or linen (Fig. 304). If a sheet of straw board has to be bent through an angle, the place for the bend should be marked and a knife cut made half through (Fig. 305).

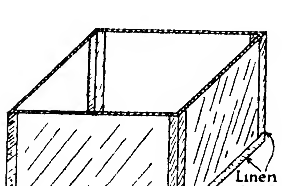


Fig. 304. Box of strawboard with strengthened corners

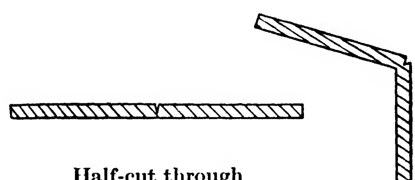


Fig. 305. Bending cardboard

A strong hinge can be constructed by sewing together two pieces of flexible material such as sateen or linen as shown in fig. 306, and then glueing it on to the two portions of board as shown (Fig. 307).

A good finish can be obtained by covering the strawboard and binding strips with black or coloured paper or cloth.

The firm of F. G. Kettle, 9, New Oxford Street, London, W.C.1,

[1] Makers. Chas. M: Higgins & Co., Brooklyn N.Y. and Farringdon Avenue, London, E.C.4.

keep a great stock of strawboard sheets, and cardboard tube and every variety of fancy paper. One very useful paper is known as flock paper; it is sold by the yard and in rolls and has a matt, cloth-like surface. It is supplied in various colours, and makes a good material for pasting on to plywood or strawboard to form the interior surface of exhibition cases.

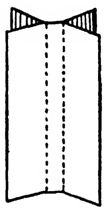


Fig. 306. Flexible hinge

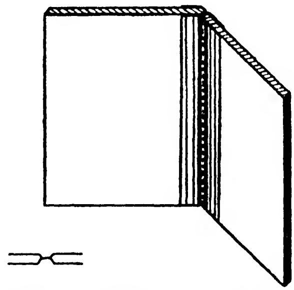


Fig. 307. Hinge glued in position

Black flock paper has an optical black finish and makes an excellent lining material for demonstration cabinets connected with light experiments. Its use in this connection can be seen at the permanent exhibition of the Lighting Service Bureau, 2, Savoy Hill, London, W.C.2.

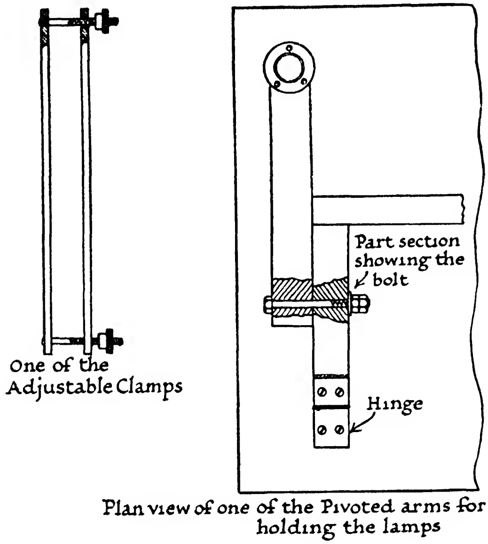
205. The preparation of lantern slides from book illustrations.

An old half plate camera is useful for this purpose. Very few amateur photographers now use half plate cameras and excellent instruments can be bought from second-hand camera dealers for less than £2, complete with one or two book form slides. New adapters can be purchased for 1 /6 to fit the ½-plate slides and so make them available for ¼ plates.

Before a lantern slide can be made it is necessary to prepare a photographic negative of the illustration and this necessitates a stand for the camera and an illuminated easel for the book.

A convenient form of home-made easel is shown (Fig. 308). A drawing board can be used for the vertical portion. If this be fixed to the baseboard with hinges it can be turned back into a horizontal position, making it easier to attach books or papers. The face of the board should be painted a dull black with two white lines across it, so that illustrations are easily centred.

Papers can be attached to the board with drawing pins and books can be held flat and firmly in position by means of two brass clamps that may be moved along the board and tightened up as required.



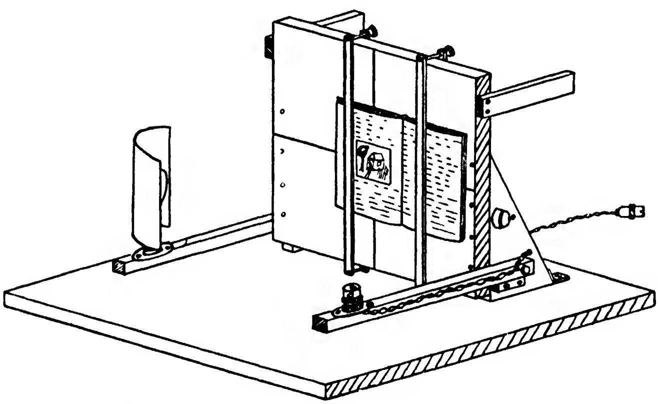
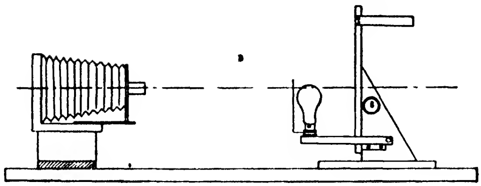


Fig. 308. A home-made easel for copying

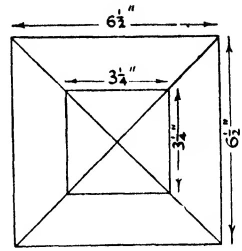
To obtain constant illumination it is best to use artificial light and two 60 watt pearl type electric lamps are fixed one on each side.

These lamps are provided with simple shades, so that no direct light from the lamps can enter the lens of the camera. The shades can be cut from tin plate. Batten type lamp holders are arranged on pivoted arms.

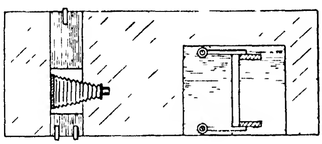
Some glossy papers give rise to troublesome reflections. A slight movement of one or other of the arms provides a cure by changing the direction of the illumination.



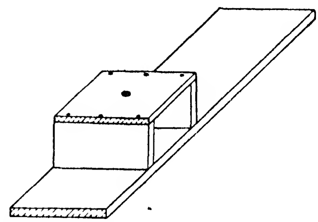
Side view of camera and easel



How to mark the ground glass screen of the camera



Plan of camera and easel



The wooden stand on which the camera is fixed

Fig. 309.

The camera can be attached with a tripod screw to a stand as shown (Fig. 309).

The dimensions of the stand should be such that the centre of the lens in its normal position is at the same height from the bench top as the centre of the easel.

The ground glass of the camera should be marked with a pencil to show the size of a lantern plate 3¼" × 3¼". To use the apparatus the illustration to be photographed is attached to the easel and the lamps switched on.

The image of the illustration is focussed on the ground glass. If it is too big to come on to a lantern plate the easel is moved farther away and the image is again focussed.

A magnifying lens should be used for critical focussing.

For copying work, process plates should be used. The writers use Wellington Ortho Process ¼ plates in conjunction with Wellington metal-hydrokinone universal developer prepared according to the formula as given on the cover of the plate box.

After focussing, the lens should be stopped down to about f16.

With the easel at a distance from the lens of 2½′, a stop of f16 and illumination from two 60 watt lamps the time of exposure is about three minutes.

Wellington Process Plates with an H and D speed of 100 have

very great latitude, an error of a minute or so makes little difference.

Time the exposure with a watch and avoid vibration of the bench during this time. Develop to full density; use a ruby safe light. Fix, wash and dry the negative in the ordinary way.

All parts of the negative corresponding to white paper in the original should be a good black.

Make lantern slides from the negatives on Wellington S.C.P. lantern plates. These are best exposed by placing the printing frame, with negative and lantern plate, below a pearl, pipless type electric lamp suspended over a bench. Develop with Wellington universal developer and fix in acid hypo.

When masking and binding up slides from book illustrations or catalogues it is advisable to mask out all printed matter. A slide that might otherwise pass for a photograph prepared from the original object can be spoilt by the inclusion of a figure number.

206. Using ebonite.

Ebonite is best marked out on the back of the sheet with an engineers' steel scriber; pencil lines may cause leakage paths.

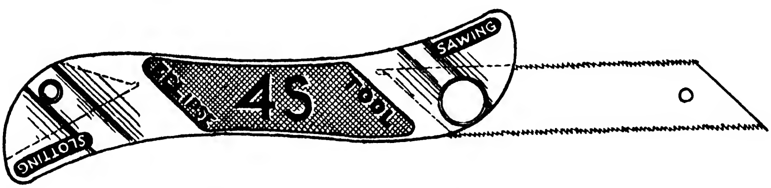


Fig. 310. The 'Eclipse' 4 S tool. *By courtesy of James Neil & Co , Ltd.*

Ebonite quickly takes the edge off an ordinary wood saw, so a hack-saw should be used for cutting it.

A very useful tool for cutting ebonite, metal and other materials is made by James Neill & Co., Ltd., Sheffield and is known as the 'Eclipse' 4 S Tool.[1] (Fig. 310). This has no frame to get in the way and limit the depth of cut.

After cutting a sheet of ebonite roughly to shape with a saw it can be clamped between jaw protectors in a vice and filed to exact size, the scribed lines serving as guides.

The surface can be rubbed down with fine glass or emery paper. This leaves it slightly brown, a good black surface is obtained by wiping it over with a rag moistened with thin machine-oil or paraffin.

[1] Sold by tool dealers for 5 /–. This includes a metal container, a holder and 15 tools.

Ebonite can be centre punched and drilled in the same way as metal. Twist drills are suitable. Some inferior grades of ebonite tend to break away in flakes at the place where the drill emerges, for this reason it is always best to drill ebonite with the sheet placed on a flat board. A thread can be cut in ebonite with a screw cutting tap, if necessary vaseline can be used as a lubricant,

Large diameter holes can be cut with a metal piercing saw (Fig. 81), or an expansion drill (Fig. 65).

207. Using uralite.

Uralite, a material made from cement and asbestos and largely used in the building trade for the construction of bungalow walls, and in the form of tiles is a valuable workshop material. It is fireproof and a good electrical insulator.

It is sold in sheets both large and small. A sheet a ¼″ thick, measuring 8′ × 4′, costs about 5/6. Other standard sizes are 6′ × 3′, and 4′ × 4′. Tiles in various colours and costing but a few pence, each measure 20″ × 10″, 24″ × 12″, and 12″ × 12″.

Uralite is very strong under compression, but is brittle and will not resist much bending. It is easily cut with a hack-saw and filed, large portions are best cut as follows.

Place the sheet on a flat surface and use the sharpened tang end of an old file to make a deep incision. A steel rule or a length of board can be used as a straight edge. Place the sheet on a table with the scribed incision facing upwards, but just over the edge of the table. Give the projecting portion of the sheet a sharp bend downwards, it will break off with a fairly clean fracture along the incision.

The tang of the file can be ground to a pointed knife edge on a carborundum wheel.

Uralite can be drilled with twist drills and countersunk with a rose bit. It tends to blunt these tools very rapidly.

208. Can openers.

In recent years various tools have been invented that cut out the top of salmon, preserved fruit, or other tin cans in such a way as to leave a smooth turned over edge.

One such tool that only costs 1/– and does its work very well indeed is known as Vaughan's Safety Roll Jr. Can Opener, No. 170B.

Tins that have been opened in this way can be used in a laboratory as water baths and in a workshop for mixing materials or as store tins.

A tin can with both ends cut out makes a good tube for optical apparatus construction.

209. Packing case opener.

Most laboratory workers have occasion to open packing cases of glassware and other apparatus. Bands of steel ribbon can be cut with the help of a cold chisel and hammer. Nailed down lids may be prised up with a cold chisel; wood chisels and screwdrivers are liable to be injured if used for this purpose.

A special tool, known as a wrecking bar, is made for opening cases (Fig. 311), but the tool par excellence for extracting nails is an automatic nail puller (Fig. 312). This pulls out the nails without bending them or spoiling the case to any appreciable extent.

210. The use of rivets.

Various rivets are illustrated (Fig. 39).

The process of riveting is quite easy and can be applied to plywood, canvas, leather, metal and many other substances. Riveted metal joints are very strong and can be used in places where heat would melt solder.

Fig. 313 shows a leather strap handled riveted to the side of a box made of 3-ply wood. The box itself can be put together with rivets by arranging strips of wood in the corners. The method of riveting on the handle is shown (Fig. 314).

Flat headed copper rivets and washers are particularly useful for this type of work.

I. Make holes in the leather and in the wood of the same diameter as the rivet.

Holes in the leather are best cut with a hollow steel punch. Rest the leather strap on a piece of old sole leather and strike the punch a heavy blow with a hammer (Fig. 315). If no punch be available use a Lancashire broach to pierce a hole. The wood should be drilled with a twist drill of the same diameter as the rivet to be used.

A suitable drill can be selected by trying the fit of a rivet in the holes of a metal drill stand.

II. Push the rivet through the holes and fit on a metal washer. The diameter of the hole in the washer should be approximately the same as that of the rivet; the latter should extend about $\frac{1}{16}''$ beyond the washer.

If the rivet be too long, use a shorter one or file or cut it to length.

End cutting nippers (Fig. 316) save much time in cutting rivets.

III. Place the head of the rivet on the closed jaws of a vice and with the rounded end of a ball-pane hammer extend and clench the rivet over the washer. A series of gentle blows are more effective than heavy ones in spreading the metal.

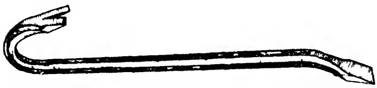


Fig. 311. Wrecking bar for opening packing cases

Fig. 312. Automatic nail puller

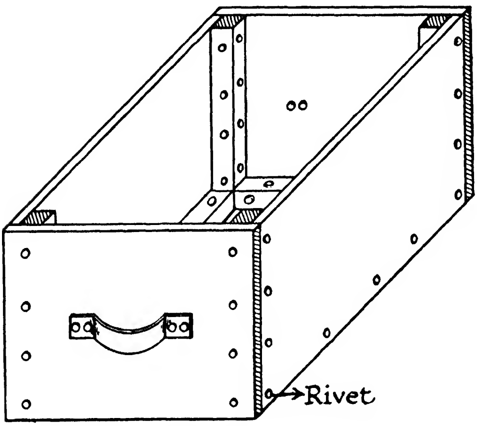


Fig. 313. Use of rivets to construct box and attach leather handles

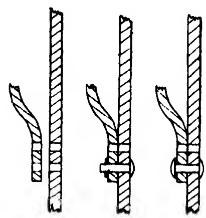


Fig. 314. Method of riveting leather handle to box

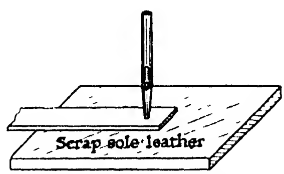


Fig. 315. Punching a hole in a leather strap

Fig 316. End cutting nippers

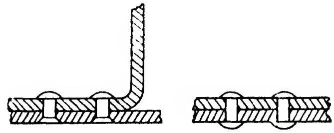


Fig 317 Riveting together metal strips

Washers are not required when hard material, such as metal, has to be riveted. Fig. 317 shows strips of metal riveted together. The chief precautions to observe when riveting are:

(1) make the fit of the rivets in the holes as good as possible.

(2) arrange for a short protruding portion.

Small brass nails make good rivets for very fine work.

211. Covering books with brown paper.

The diagrams (Fig. 318) show a simple and effective method of folding brown paper to form a slip-on cover for a book.

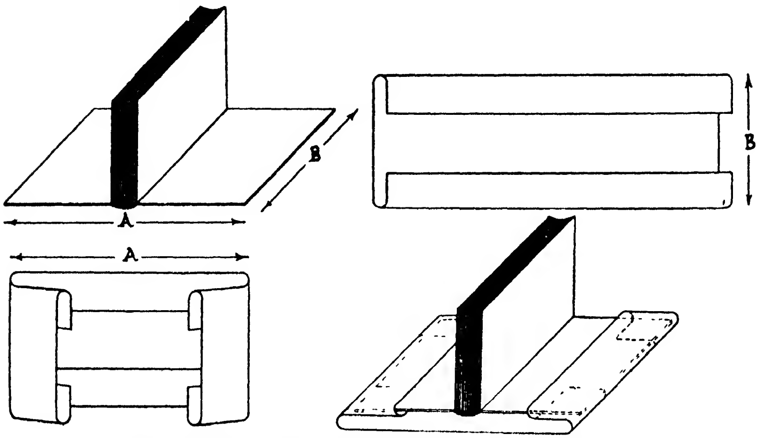


Fig 318. To make a slip-on paper book cover

212. The temporary repair of electric heating elements.

The resistance portion of open wire type electric heaters are usually made of nickel chromium alloy. If a wire gets thin and fuses at some point it is sometimes possible to effect a repair that will last a considerable time, by carefully scraping and cleaning the broken ends, then bending around a small brass bolt and clamping up tightly between two brass nuts.

A steel bolt and nuts are unsuitable owing to rapid oxidation at high temperatures.

213. The protection of tools from rust.

Tools can be protected from rusting by wiping them over with an oily rag. In hot, moist countries it is advisable to do this after the day's work in the case of all tools that have been handled. If tools are to be stored and not used for some time they should be well oiled or greased.

Never use linseed oil. Ordinary engine oil is suitable, but one of the best rust preventing oils is 3-in-One.

An excellent method of protecting tools with grease is to dissolve vaseline in petrol and either dip the tools in the fluid or paint it on with a brush. Vaseline is carried to every crevice and left as a thin film when the petrol evaporates.

CHAPTER X

DRAWINGS AND DESIGNS

214. Workshop drawings.

BEFORE starting the construction of a piece of apparatus it is often helpful to prepare a rough sketch. Usually such a sketch is all that is necessary or desirable when scrap material or odds and ends have to be utilised as material, designer and constructor being one and the same person.

When a design is being prepared for the guidance of other people or the object drawn has to be made in quantity or for use with other parts a proper scale drawing should be made.

The reading of a workshop drawing requires some knowledge of the art of the draughtsman and at this stage a few notes on how to read a drawing may not be out of place. Fig. 319 is a freehand sketch of a small lifting electro-magnet. Such a sketch fails to show anything of the interior construction and would not be sufficient for workshop purposes.

A view, in silhouette, as seen from one side is known as an elevation. An elevation of the magnet as seen from A is shown in fig. 320. More information with regard to the shape of the magnet and the wooden terminal block is provided by a second drawing of the magnet as seen from position B at right angles to position A (Fig. 321). The steel part of the magnet is cylindrical in form, but this fact is not conveyed by elevation drawings only although some idea of form can be given by shading (Fig. 320).

Plan views as shown in figs. 322 and 323, and studied in conjunction with the two elevations yield full information with regard to the exterior form of the magnet.

In the side elevation, fig. 321, the hole through the brass knob cannot be seen.

If the brass became transparent the outline of the hole would be seen in the position shown by the two parallel lines composed of short dashes.

This is the conventional method of indicating the position of unseen holes or parts.

A drawing of the magnet in section is shown in fig. 324. This is a section in elevation across the line *a b* (Figs. 322 and 323).

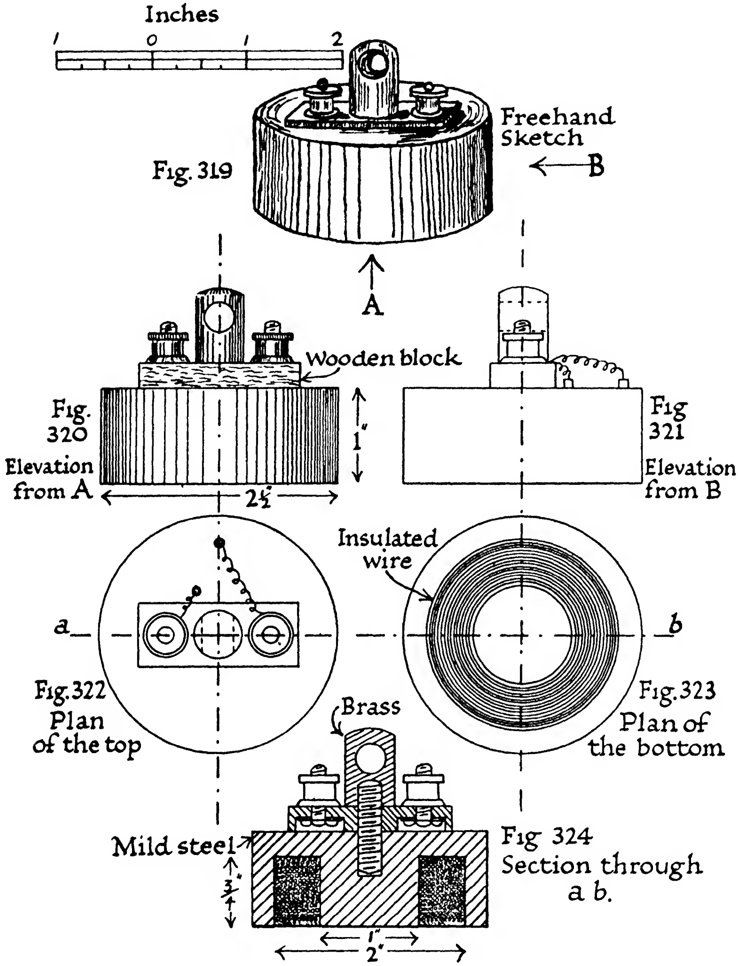


Fig. 319

Fig. 320 Elevation from A

Fig 321 Elevation from B

Fig. 322 Plan of the top

Fig. 323 Plan of the bottom

Fig 324 Section through a b.

Centre lines made of dots and dashes are a common convention and are useful for indicating the relative position of the different parts as shown on adjacent drawings.

Dimension lines are usually shown as firm lines provided with arrows.

Parts shown in section are cross hatched and screw threads can be indicated by thick and thin lines. Various conventions are shown in fig. 325. In fig. 324 the tops of the terminals and the attaching nuts imbedded in the recessed part of the wooden block are not shown sectioned. The design of those parts follows

standard practice and can be left to the imagination of the reader. To show them sectioned would only add to the complexity of the drawing. Practical details regarding the construction of this magnet are given in Chapter XI.

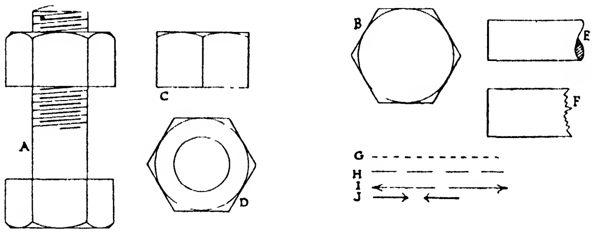


Fig. 325. Conventional methods of representation
A. Nut and bolt
B. Plan view of the head of a bolt
C. Side elevation of a nut
D. Plan view of a nut
E. A rod or shaft shown discontinued
F. A piece of wood shown discontinued

Many of the drawings used to illustrate previous chapters are known as isometric projections. These are simple to draw and have many advantages for workshop purposes.

In fig. 326 a metal block provided with clamping screws is shown in isometric projection. An artist drawing this in perspective would show the lines AB and CD as converging lines and BD shorter than AC. An isometric projection shows both AB and CD inclined at an equal angle to the horizontal, usually 30°, and BD = AC. This type of drawing enables vertical or horizontal measurements to be made at any part of the drawing.

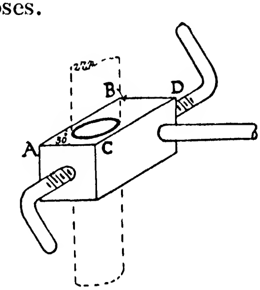


Fig. 326. Isometric projection of a metal block with clamping

A circle becomes distorted in an isometric projection and it should be noted that certain angular and diagonal measurements cease to be correct. The angle BAC is not a right angle in the drawing and BC is not the true diagonal distance between B and C.

215. The preparation of a drawing for reproduction by the line-process.

Drawings to be reproduced in books and magazines by the line process require special care if satisfactory blocks are to be made by the photo-engraver.

The drawings should be made on a smooth white ground such as Bristol board or best quality type-writing paper that is free from a water-mark. Use best quality, very black Indian ink and

remember that nothing in the way of half tones or coloured washes can be reproduced by the line process. Shading must be done with firm black lines and clean white spaces between. Any wording associated with the drawing is best put in by the printer; its position and nature can be inserted on the drawing in blue pencil since blue reproduces as white in the photographic stage of line block making and will not show in the reproduction.

Drawings are best made about twice the size they will finally appear and each one should have the reproduction size indicated in blue pencil.

Care must be taken to avoid ambiguity when inserting the reproduction size. A reproduction size indicated as $\frac{1}{2}$ linear implies a reproduction having horizontal and vertical lines reduced to $\frac{1}{2}$ the length shown in the original, but covering $\frac{1}{4}$ the area occupied by the latter. An instruction such as, reduce to $\frac{1}{2}$ might mean reduce to $\frac{1}{2}$ linear or reduce the area to $\frac{1}{2}$.

Drawings for reproduction should be clean, free of pencil marks and must not be folded. All lines should be clean and not woolly, and very fine lines should be avoided.

216. The preparation of lecture-room diagrams.

Large wall-diagrams can serve the useful purpose of illustrating lectures and of creating 'atmosphere.' They can be drawn in pencil on large sheets of good quality drawing paper, then lined in with Indian ink and colour washed with diluted Indian ink or poster colours. The latter can be bought in *6d.* pots in a great range of tints.

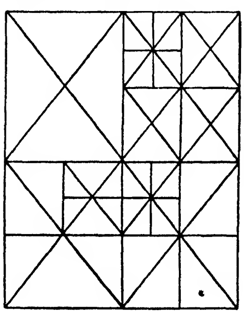


Fig. 327. The diagonal method of dividing an illustration preparatory to enlargement

A book illustration can often be used as an original for enlargement; this can be done in various ways. The following are two methods.

(1) The original drawing can be divided into squares, or rectangles and triangles, by fine pencil lines and the paper to receive the enlarged drawing is divided similarly; it is then a simple matter to locate corresponding points. The method of forming triangles by drawing diagonals (Fig. 327) is less confusing than the square method and it is an easy matter to draw additional diagonals over areas where much detail has to be measured. If the original must

not be marked it can be covered with suitably divided tracing paper.

(2) All measurements taken from the original can be multiplied a suitable number of times by stepping out with dividers, two, three or four times according to the degree of enlargement required, the trouble of doing this can be avoided by the use of proportional dividers.

217. The designing of apparatus.

In recent years there has been a tendency for science equipment to become more and more elaborate and possibly the pendulum has swung rather too far in this direction.

A visit to the Science Museum or the Royal Institution in London and inspection of the apparatus used by the late Lord Rayleigh and Faraday in their researches can serve to demonstrate the use of home-made apparatus and of familiar things.

The following is an extract from *The Times* with reference to Lord Rayleigh's instruments.

'Lord Rayleigh, as many of his visitors were surprised to discover, took common glass-tubing, sealing-wax, blocks of coarse wood, cardboard, zinc, or whatever came to hand for the construction of apparatus of great technical complexity. We find him using a sheet of smoked glass, a collection of pebbles, and a square of corrugated metal to research into the reflection of sound. For a "bird-call" to test the vibration of sound-waves outside the range of the human ear he employs a simple tin bearing the inscription, "This is sold as a mixture of coffee and chicory." The card of invitation to a Guildhall banquet is cut and pasted into shape to act as the transmission vessel for certain experiments on the motion of fluids, and the vibration of a bell is brilliantly dissected when the bell is made of a disc of zinc, a cylinder, and two hollow truncated cones.'

Tyndall, writing fifty-six years ago concludes the pages of a delightful little book called *Lessons in Electricity at the Royal Institution*,[1] with the following words, which remain true to the present day.

'And here, if I might venture to do so, I would urge upon the science teachers of our public and other schools that the immediate future of science as a factor in English education depends mainly upon them. I would respectfully submit to them whether

[1] Longmans, Green & Co., 1876. Is scarce, can sometimes be obtained secondhand.

it would not be a mistake to direct their attention at present to the collection of costly apparatus. Their principal function just now is to arouse a love for scientific study. This is best done by the exhibition of the needful facts and principles with the simplest possible appliances, and by bringing their pupils into contact with actual experimental work.

'The very time and thought spent in devising such simple instruments will give the teacher himself a grasp and mastery of his subject which he could not otherwise obtain; but it ought to be known by the head masters of our schools that time is needed, not only for devising such instruments, but also for preparing the experiments to be made with them after they have been devised. No science teacher is fit to meet his class without this distinct and special preparation before every lesson. His experiments are part and parcel of his language, and they ought to be as strict in logic, and as free from stammering, as his spoken words. To make them so may imply an expenditure of time which few head masters now contemplate, but it is a necessary expenditure, and they will act wisely in making provision for it.'

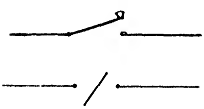


Fig. 328. Symbols for a switch

When considering the home-construction of apparatus it is always well to start by reducing it to essentials and after that to build up details based on mechanical, electrical, optical or other requirements.

A few examples will illustrate the method.

The common conventions for a switch in electrical diagrams are shown in fig. 328, namely some means of bringing two conductors into electrical connection. Switches are manufactured in a multitude of forms, but they must all satisfy the above requirement which can usually be brought about by simple means. Complexity in design is caused by the need for mechanical strength, sufficient electrical insulation, quick break-action, low resistance contacts and other requirements. If those and the fundamental requirement can be satisfied a switch constructed from scrap pieces of brass mounted on a baseboard of American whitewood may function just as well as an expensive commercially made switch mounted on polished ebonite.

An optical lantern for the projection of slides can be reduced to a lamp, surrounded by some arrangement for preventing the escape of stray light, a condenser, a slide-holder and a lens. The lamp, condenser, slide-holder and lens must be kept in correct relative position and be capable of a certain amount of adjustment.

A screw clip on the rubber tube joining the boiling tin and the side reservoir enables the supply to be regulated.

A radiation switch. (Fig. 338 and Plate IIIA, page 194.)

This illustrates a mechanism that has found various practical applications, namely the automatic switching on of lights, temperature control and self-winding clocks.

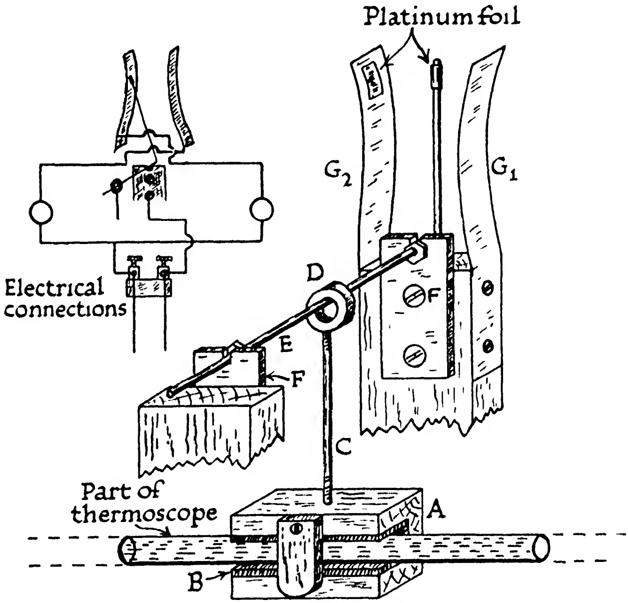


Fig. 338. A radiation switch

An ether thermoscope with arms bent at right angles is mounted in a rocking support. Thermoscopes of this type are supplied by instrument dealers for about 3/– each.

With the rocker as shown in Plate IIIA, a contact is made and when the apparatus is connected to the mains the right hand lamp will light up. This causes the ether to be driven into the left hand bulb. The balance is upset and the rocker moves so that connection for the right hand lamp is broken, but made for the left hand one. After a quarter of a minute or so the balance is again disturbed and the rocker returns to the initial position. A constant see-saw motion is set up.

A. Block of wood. A groove is cut in this and lined with cork B, so that the thermoscope is a press-in fit and cannot twist

out of position. A side clip enables the thermoscope to be fixed in position or removed as required.

B. Cork: See above.

C. Cycle spoke: This has a No. 9 B.A. thread cut on both ends. One end screws into the block of wood and the other into a Meccano collar [**14, 100**].

D. Meccano collar: This is soldered to the spoke E.

E. Cycle spoke: One end is bent at right angles. It rests in slots cut in the bearing plates F and F, and small B.A. nuts are soldered on to prevent any side movement.

F & F. Bearing plates: These are made of strip brass and are attached with screws to the wooden uprights [**54, 57**].

G1 & G2. Contact arms: Made of strip brass. If the mechanism is to be kept in action for a long time it is an advantage to attach small pieces of platinum foil to these arms and to the cycle spoke E. The foil can be fixed in position with a small amount of ordinary solder.

In Plate IIIA, page 194, the lamps and thermoscope bulbs are shown partly blackened with Roscoe cylinder black [**202**]. This helps to increase the rate of action of the mechanism.

A nickel pendulum. (Fig. 339.)

This apparatus can be used to demonstrate that nickel ceases to be attracted by a magnet when heated to a sufficiently high temperature.

A small tongue of nickel is riveted to a thin copper disc and suspended in front of a magnet. A small Bunsen or spirit flame is placed below the tongue of nickel. The temperature of the nickel rises and it soon ceases to be attracted by the magnet and falls away. The copper disc promotes rapid cooling. The nickel is again attracted and again heated, so the pendulum-like motion is maintained.

A. Tongue of nickel. This is $\frac{1}{2}''$ to $\frac{5}{8}''$ long and can be cut with a hack-saw from a nickel coin to be obtained from a travel agent. Some Continental coins are made of nickel and are easily picked out with a magnet. Portions of old nickel electrodes provide another source of nickel. They can be purchased for a few pence from an electroplater.

B. Copper disc. Use a piece of sheet copper about $\frac{1}{32}''$ thick and cut a disc 1″ in diam. [**63**]. The nickel can be attached to the disc by means of small brass nails cut short to form rivets.

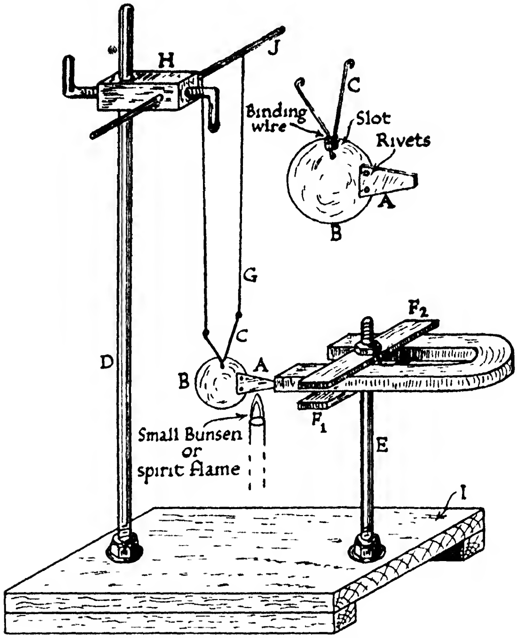


Fig. 339. A nickel pendulum

C. Arms for disc. These are formed from a piece of No. 18, S.W.G. copper wire. The wire can be passed through a hole drilled in the disc and bound with fine wire, as shown in the enlarged sketch, fig. 339. The slot filed in the disc prevents the arms from slipping out of position.

D. Steel rod: Use a 12″ length of bright drawn $\frac{1}{4}''$ diam. mild or cast steel.
The lower end has a $\frac{1}{4}''$ Whit. thread cut on it [**93**] and is provided with two nuts and washers for attaching it to the base-board [**113**].

E. Steel rod: Material similar to D. A thread is cut on both ends. This rod should be long enough to enable a magnet to be clamped 1″ above a Bunsen burner or spirit lamp placed on the base-board.

F1 & F2. Magnet clamp: Made of brass strip. The central hole in F2 is drilled $\frac{1}{4}''$. The hole in F1 is drilled $\frac{3}{16}''$ and tapped with a $\frac{1}{4}''$ Whit. thread [**104**]. F1 screws on to rod E and is supported with a back nut [**107**]. This nut does not show in the illustration.

G. Fine copper wire: The double suspension of fine wire keeps

the swinging disc in the same plane all the time. The fine wire off the secondary winding of an old Ford spark coil is very suitable.

H. Clamp: Made from $\frac{1}{2}''$ square brass [**87**, **104**, **85**, **102**].

I. Baseboard [**153**].

J. Horizontal rod: A length of $\frac{3}{16}''$ diam. steel rod or a Meccano axle.

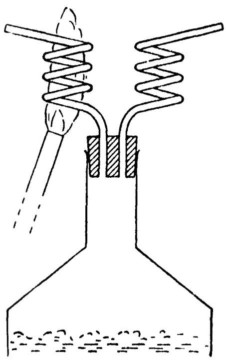


Fig. 340. Apparatus for producing superheated steam

Apparatus for producing superheated steam. (Fig. 340.)

An oil-can made of tin plate is provided with a good cork bored with holes to take two spirals of copper tubing. The tubing is $\frac{1}{4}''$ in diameter and is wound into spirals of $1''$ internal diameter. If the tubing be annealed before use it is an easy matter to form a spiral by winding it round a broom-stick.

When water is boiled in the can steam issues from the two tubes.

If one spiral be heated with a Bunsen flame it is possible to char paper or light a match in the invisible jet of superheated steam that is produced.

Steam mixed with drops of water issues from the unheated spiral.

Reference: *Engines* by E. N. da C. Andrade, G. Bell & Sons. Chapter II, 'Learning about steam.'

Searle's apparatus for measuring thermal conductivity. (Plate IIIB. Fig. 341.)

This apparatus consists of a rod of metal A, fig. 341, measuring $12''$ long and $1\frac{3}{4}''$ in diameter formed of the particular metal under test. Brass is suitable for instructional purposes.

To one end of the rod is soldered a box B provided with an inlet and an outlet pipe for steam. A coil of copper tubing is soldered to the other end of the rod. Water can be passed through this tube and thermometers can be fixed in the tubes C1, and C2, to record the rise of temperature of the circulating water. Two tubes D1 and D2, are screwed into the rod to enable thermometers to be inserted for determination of the temperature gradient. The apparatus can be housed in a wooden case and before use the rod, steam box and copper tubing must be well packed with cotton wool or other poor conductor of heat.

The use of the apparatus is described in many physics text-books; an account with a worked example can be found in *Heat* by W. J. B. Calvert, Edward Arnold & Co.

The apparatus can be constructed at a cost of about 9/–. The thick brass rod is the most expensive item.

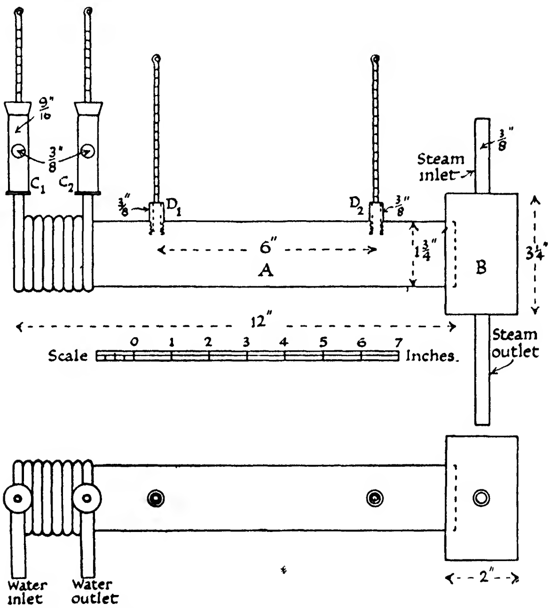


Fig. 341. Searle's apparatus for determining the thermal conductivity of a metal

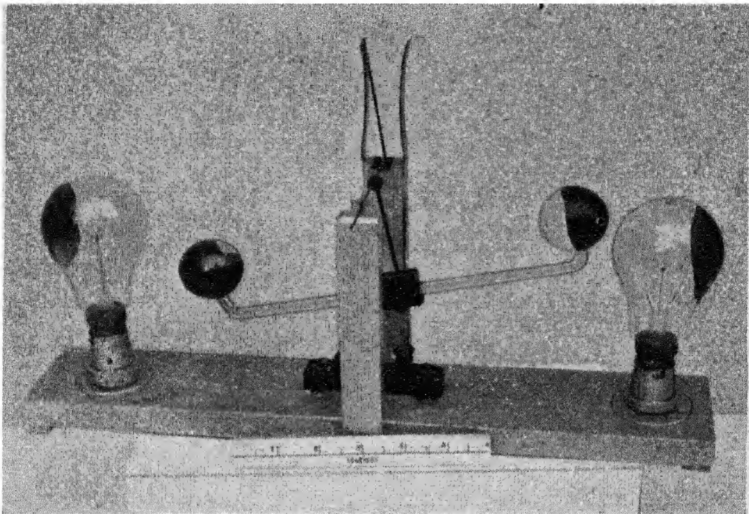
The steam box is made of sheet brass and is formed from two discs and a strip of metal bent to cylindrical form.

A suitable size for this cylinder is $3\frac{1}{4}''$.

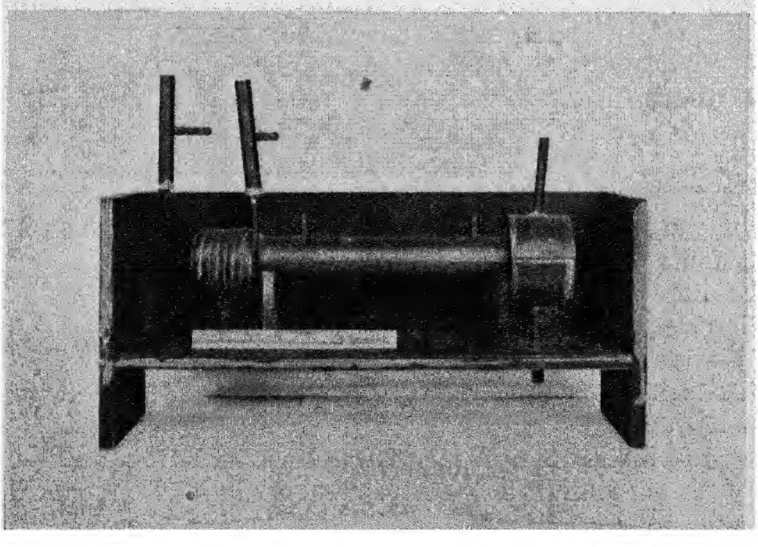
Find a tin or a bottle of approximately this size and bend round it a $2''$ wide strip of thin brass. Bind the strip with black iron wire, then slip it off the tin or bottle and solder the edge to form a cylinder [**78**].

Cut two discs of a diameter $\frac{1}{8}''$ greater than that of the cylinder [**68**]. In one disc cut a hole of diam. $1\frac{3}{4}''$ [**70, 71**]. It should be a tight fit on the rod A [**69**]. The discs can now be soldered to the cylinder and two pieces of $\frac{3}{8}''$ diam. brass tube should be soldered into the sides of the steam box to provide inlet and outlet pipes [**143**]. Before the steam box be soldered to the rod A the copper coil for the circulating water must be constructed and soldered in position. The coil is made from $\frac{1}{4}''$ diam. copper tubing [**83**].

PLATE III



A. A radiation switch



B. Searle's heat conductivity apparatus

Before coiling round the rod A it must be annealed to render it soft.

After annealing give the tube a good clean with emery cloth then wind it round the rod A to form eight coils.

The brass rod A and the copper of the coils are such good conductors of heat that it is necessary to make special arrangements for soldering. Support the rod on a triangular stand and heat the centre of the rod with a cluster of Bunsen burners. This prevents undue cooling of the solder. Use a hot soldering iron and Baker's fluid or zinc chloride as flux. Fill all the spaces between the coils with solder.

When the soldering of the coils is finished the steam box can be soldered on. The rod A should project about $\frac{1}{4}''$ into the box.

The tubes C1 and C2 are made of brass with side tubes soldered in at right angles to form T-pieces [**144**]. To the base of each tube C1 and C2, is soldered a brass disc, these are drilled with $\frac{1}{4}''$ diam. holes and soldered to the ends of the copper coil.

The tubes D1 and D2 are made of $\frac{3}{8}''$ diam. brass tube and screw into holes drilled and tapped for $\frac{3}{8}''$ brass gas thread [**115**].

To obtain good thermal connection between the thermometer bulbs and the rod A it is advisable, when using the apparatus to put a little mercury in each tube. Mercury forms an amalgam with solder, so the latter should not be used to attach the tubes D1, and D2, to A.

In Plate IIIB the apparatus is shown arranged in a box made of seven-ply wood. One side was unscrewed to enable the photograph to be taken.

It is best to pass water through the coils from a constant level apparatus.

Apparatus illustrating spheroidal condition of water. (Fig. 342.)

This apparatus enables various effects associated with the spheroidal condition of water to be demonstrated to a large audience. It can be placed in a lantern of the open-stage type and projected on a screen. A brass plate is brought to the necessary temperature by means of an electric heating unit.

A. Asbestos cement base-plate: This can be cut from a sheet of the material [**207**].

B. Electric heating unit: A unit of the type used in electric irons and kettles is suitable. Most electricians stock spare units. The metal connections at the ends of the unit are drilled and fitted with terminals.

C. Brass plate: This is clamped down and held in close contact with the heating unit.

D. Clamping strips: Made from $\frac{1}{2}'' \times \frac{1}{8}''$ strip brass, drilled and fixed to the base-plate with $\frac{3}{16}''$ nuts and bolts.

A large spheroidal globule can be built up on the heated plate by dropping warm water on it from a fountain-pen filler. The

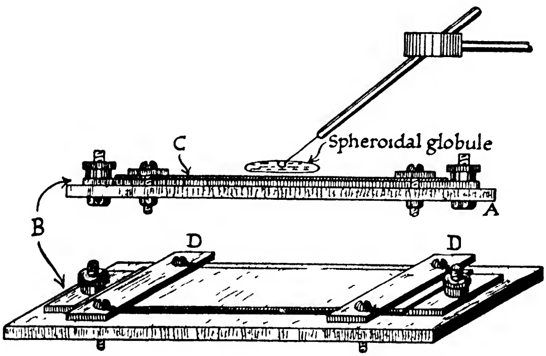


Fig. 342. Apparatus illustrating spheroidal condition of water

globule can be prevented from sliding away by forming it about a little loop of platinum or nickel-chromium wire. The space between the globule and the heated plate and the explosion on cooling is made evident by projection.

Apparatus for demonstrating recalescence phenomena. (Fig. 343.)

A length of steel wire is arranged between two supports and made red hot by passing an electric current through it. By means of a magnifying pointer it can be shown that during heating the wire expands, contracts, then expands again. On turning off the current the wire contracts, expands, then contracts.

By presenting a magnet to the red hot wire it can be shown that it is non-magnetic.

A. Steel wire: 24″ of No. 22, S.W.G.

This can be bought from tool merchants or piano dealers. It can be made red hot by connecting it to the mains in series with an arc lamp resistance or by means of a transformer. The correct length to use in conjunction with a particular resistance or transformer can best be found by experiment. The writers have found 24″ a suitable length when connected to the 25 volt terminals of a transformer.

B_1 and B_2. Vertical supports: Two 14″ lengths of ¼″ diam. steel-rod threaded at the ends, ¼″ Whit. [**93**].

C. Baseboard: 26″ × 3″ × ¾″. The vertical rods are attached to the baseboard with nuts provided with washers.

D. Bearing-support: A short length of strip-brass attached to the baseboard by two wood-screws [**54–58**].

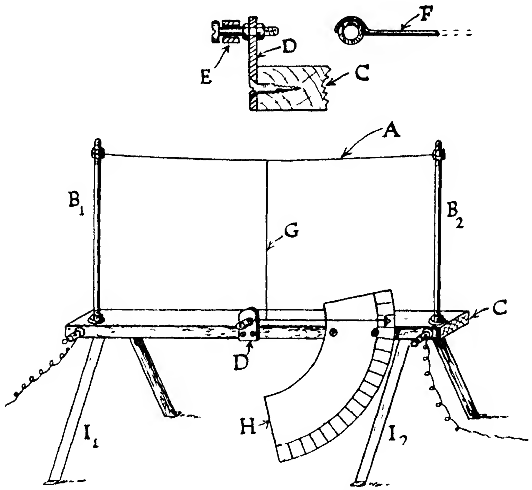


Fig. 343. Apparatus for demonstrating recalescence phenomena

E. Pointer-bearing: The axle consists of a small bolt fixed to the bearing support by means of two nuts. The moving part is a short length of brass tube that is an easy fit on the unthreaded portion of the bolt.

F. Pointer: A length of copper wire, about 18 gauge, soldered to the brass tube mentioned above. The triangular tip can be made from copper foil or paper.

G. Connection: This is a piece of very thin copper wire, about 32 gauge, making mechanical connection between the heated steel wire and the pointer. It is twisted round the centre of the steel wire and attached to the pointer 1½″ from the bearing. The secondary windings of old Ford spark coils provide a source of fine copper wire.

H. Scale: This can be cut from tin plate, and attached with screws to the side of the baseboard. A good effect is obtained by painting it black and marking the divisions in white.

I_1 and I_2. Supporting legs: These can be made from two lengths of strip steel, held in a vice and bent cold [**86**]. The strips can be attached to the baseboard with wood screws.

Electrical connections: Connections are made from terminals to the two vertical supports B_1 and B_2.

The construction of lantern bodies. (Figs. 344 to 355 and Plate IVA.)

Many optical experiments require some arrangement for holding lenses and housing a lamp in a light-tight, but ventilated body.

A lantern body with many uses for lecture demonstrations can be constructed with a framework of angle steel or Meccano girders.

Figs. 344 and 345 show the method of building up the framework. If Meccano girders be used $12\frac{1}{2}''$ and $9\frac{1}{2}''$ girders give a useful body-size. They can be fastened together with Nettlefold's pressed bolts and nuts $\frac{1}{8}''$ diam. by $\frac{3}{4}''$ round-head, bought in gross packets. To give rigidity to the framework, small triangular pieces of sheet-brass or aluminium are bolted on at the corners of the back opening (A, Fig. 344). Girders C and D, figs. 345 and 344 fixed to the front, provide a guide for lens attachments and E is a strip of brass bent at right angles to support a lens, details of this support are given later.

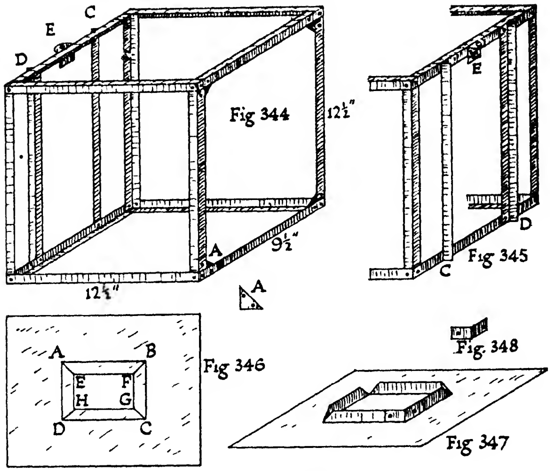
When the framework has been built up the inside measurements should be taken and the sides, front, and top closed in with sheets of tin plate carefully marked out and cut to size. If, during the construction work, it is found that bolts come in one another's way they can be cut short with a pair of side or end-cutting nippers. Bolts so treated are often difficult to fit with a nut again if for any reason they have to be taken out and replaced.

The difficulty can be overcome by gripping the head of the bolt in a vice or a pair of pliers, before placing it in position again, and filing the cut end to a bevel.

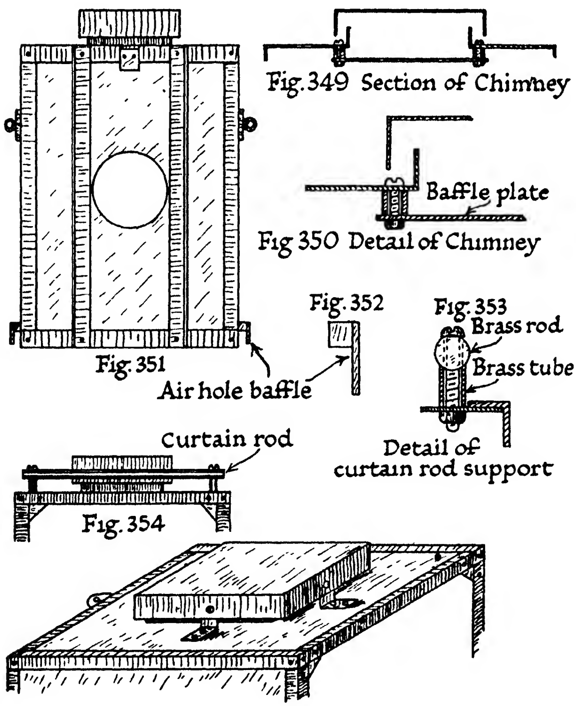
It is sometimes necessary to cut small sectors out of the corners of the sheets to allow clearance for the bolts and nuts used in fastening the corners of the framework.

The sheets can be attached to the framework with nuts and bolts of the type used for the framework itself. For the sake of neatness all nuts should be kept on the inside.

In Plate IVA a lantern body is shown with the top sheet made of corrugated sheet aluminium as used for the step-boards of motor-cars. This has a particularly pleasing appearance and radiates heat well, but its use is not necessary, tin-plate can be used instead.



Figs. 344–348.
Framework and chimney construction of a lantern body



Figs. 349–354. The construction of a lantern body

*

The top is provided with a chimney. This is made by cutting the top sheet as shown in fig. 346 along the marked out lines AE, BF, CG, DH, and along EF, FG, GH, HE.

This can be done with a hammer and cold chisel. The flaps formed are turned up at right angles to the main surface (Fig. 347).

Small corner pieces fig. 348 are attached with nuts and bolts to the ends of the flaps to close in the triangular-shaped gaps. One corner piece is shown fitted in fig. 347.

A cover for the chimney opening can be made from sheet brass or tin plate as described in Sec. 75. It can be kept in position with 1″ × 1″ Meccano angle-brackets or 2″ lengths of ½″ wide strip-brass bent to a right-angle.

The chimney can be made perfectly light-tight by fixing a baffle-plate as shown in figs. 349 and 350. Short lengths of brass tubing can be used as distance-pieces.

The sheet of metal used for covering in the front, fig. 351, has a circular opening cut in it.

If an ordinary lantern condensing lens be available it is well to cut this opening with a diameter ¼″ less than the outside diameter of the condenser mount.

A few air holes can be drilled along the bottom edges of the two side sheets and made light-tight with outside baffles, figs. 351 and 352, made from a piece of strip-brass soldered to a length of square-brass and attached to a side with nuts and bolts.

A rod, for a rear curtain of black cloth, can be arranged as shown in figs. 353 and 354. In Plate IVA a circular shaped side window is shown. It is simpler to use a piece of square glass. A frame to hold it can be built up of ¼″ square section-brass, fig. 355. The square sections should be soldered together then drilled with ⅛″ diam. holes.

A square plate of brass provided with a circular hole and attached to the outside serves to keep the glass in position when the frame is bolted over a circular hole cut in the side of the lantern body. If deep blue glass cannot be obtained a combination of ordinary red and blue, or red, blue and green glass can be used.

A good finish can be given to the body by painting it with heat resisting stove-enamel or Roscoe cylinder-black [202].

A projection microscope. (Plate IVA, page 209.)

The lantern body already described can be used to build up a projection-microscope.

The body houses an arc-lamp, or a projection-type filament-lamp and the light is concentrated by means of a $2\frac{1}{2}''$ diam. plano-convex condenser on to the microscope slide.

A simple method of mounting a small condenser is shown in fig. 361.

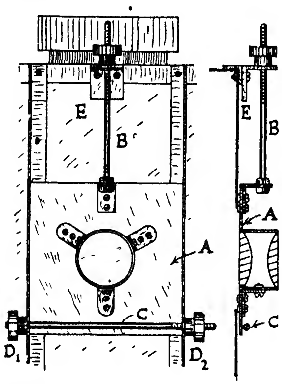


Fig. 361. Method of mounting a small condenser

A. Brass-plate: This is cut square and slides easily between the two guides attached to the front of the lantern body (C & D, fig. 345).
A circular hole is cut in the brass-plate [**68, 71**]; this should be a little less in diameter than that of the condenser. The mount holding the components of the condenser can be drilled and attached to the plate with the help of small nuts and bolts and Meccano angle-brackets, or suitably bent strips of brass.

B. Vertical steel rod: This is $\frac{3}{16}''$ diam. threaded $\frac{3}{16}''$ Whit. [**93**]. The lower end is attached by two nuts to an angle-bracket that is fixed to the brass plate. The upper end of the rod, provided with a terminal nut, passes through a hole in the bracket E. The terminal nut enables the condenser to be adjusted for height.

C. Horizontal steel rod: This passes through holes in the front angle-girder guides and prevents the brass plate A from swinging forward when the lantern body is carried about. A $\frac{3}{16}''$ diam. rod is suitable, threaded at each end $\frac{3}{16}''$ Whit. The rod is provided with two terminal nuts D1 and D2. D1 should be screwed tight on to the rod and the rod at this end should be riveted over to prevent D1 from coming undone. D2 should be an easy fit.

Any good quality microscope can be used. It is placed in a horizontal position with its optical axis in line with that of the condenser. If necessary it can be raised on a block of wood.

It is advisable to place a tank containing water between the condenser and the microscope to prevent overheating of the microscope slide or the microscope objective.

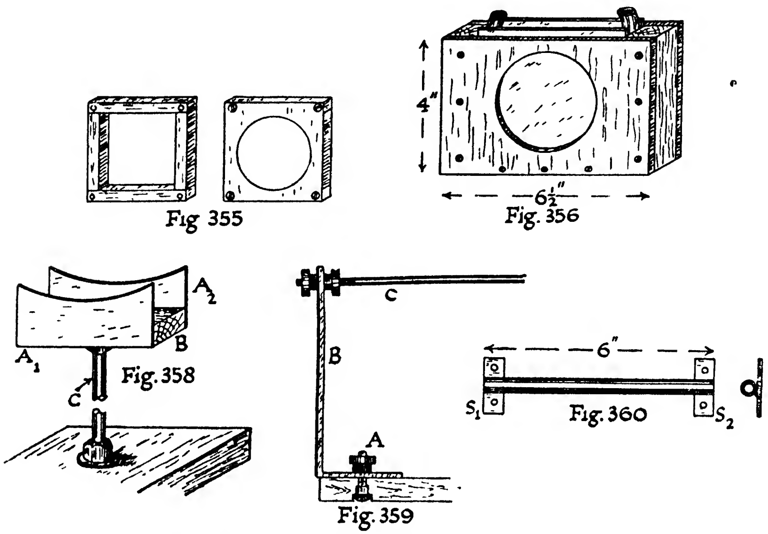
A method of building up a tank is shown in fig. 356. It consists of a wooden framework holding two rectangular plates of glass.

A length of rubber gas tubing is compressed between the plates and forms a water-tight joint.

Fig. 358 shows a clip for holding the tank.

A1 & A2. Clips: Made of sheet-brass or copper.

B. Wooden block: The width of this block should equal the width of the tank. The block is fixed to a vertical rod.



Figs. 355–360. Fittings for projection apparatus

C. Vertical rod: Steel $\frac{1}{4}''$ diam. A $\frac{1}{4}''$ Whit. thread is cut in the wooden block and the rod screwed in and made firm by means of a back-nut [107]. The lower end of the rod can be screwed into a base-board and made secure in the same way.

Plate IVA shows a metal screen arranged in the front of the microscope to cut out stray light. The screen is suspended from two horizontal $\frac{1}{4}''$ diam. steel rods and rests against two L-shaped supports. Fig. 359 shows the method of securing the supports to the baseboard.

A. Carriage bolt: $\frac{1}{4}''$ diam. provided with a terminal nut.

B. L-shaped support: made of $\frac{1}{2}'' \times \frac{1}{8}''$ black mild-steel bent cold in a vice.

C. Steel rod: $\frac{1}{4}''$ diam. and provided at the screen end with two terminal nuts. The other end of the rod slides into a tube attached to the side of the lantern body.

The method of attaching this tube is shown in fig. 360. The tube is made of brass or copper and is soldered to two strips of brass S1 and S2. Flat places should be filed on the tube before soldering. A black cloth placed over the rods is effective in stopping stray light.

Optical bench and spectrum projection apparatus. (Plate IVB, page 209, and Figs. 362 to 366.)

Fig. 362 shows a method of arranging a small optical bench. The wooden parts A, B and C are made from seven- or five-ply wood, D and E are straight lengths of $\frac{3}{8}''$ square-brass attached to the wooden ends with countersunk head screws. A more secure and accurate attachment of the rods to the ends can be obtained by adopting the arrangement shown in fig. 363, the rods being soldered to a brass plate and then attached with screws to the wood. The bench can be used for the projection of a large spectrum by the Hartridge diffraction-grating method.

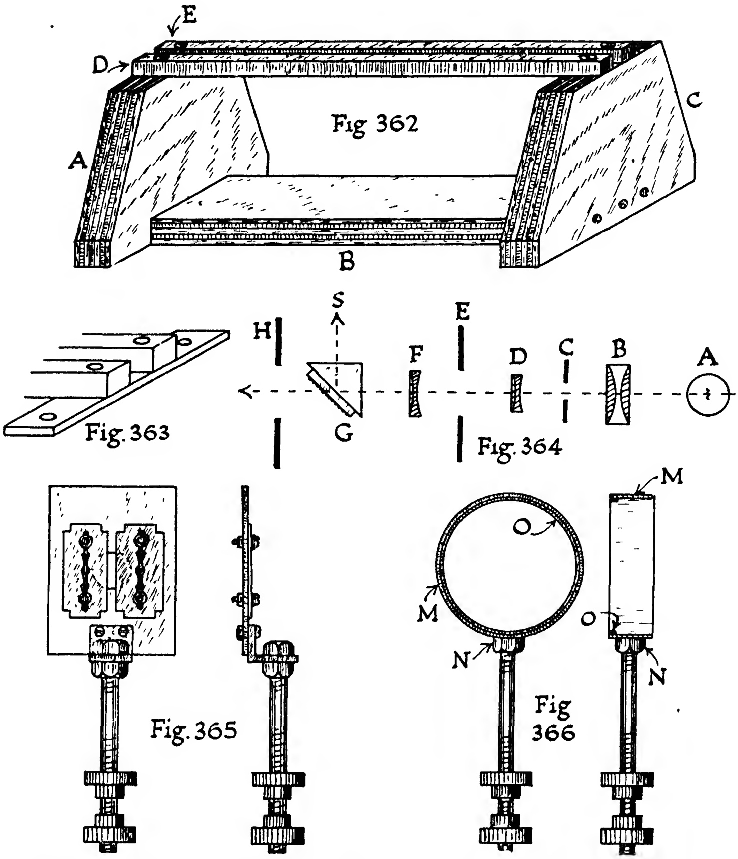
Fig. 364 shows the optical arrangement.

A. Arc lamp or concentrated-filament projection-lamp.
B. A small condenser of about 5·5 cms. diam. and 6 cms. focal length.
C. A slit approx. 5 mm. by 1 mm.
D. Achromatic lens. Approx. 3·8 cm. diam. and focal length — 5·5″.
E. A diaphragm to cut out stray light.
F. Achromatic lens. Approx. 5·4 cm. diam. — 10″ focal length.
G. An optically worked right-angled prism with a replica of a Rowland diffraction-grating, 14,438 lines per inch mounted on the hypotenuse.
H. A screen to cut out stray light.

Each of these components will be considered in detail.

A. The illuminant: A direct-current arc is best. A 10 amp. enclosed arc lamp as made by the Westminster Engineering Co., Willesden, London, yields good results on A.C. or D.C. All arcs worked from A.C. tend to wander about the carbon tips. A 10 amp. Triumph Focuslite, low voltage filament-lamp gives fairly satisfactory illumination of the slit.

B. Condenser: This is similar to the condenser used and described for a projection microscope.



Figs. 262–266. Optical bench and spectrum projection apparatus

C. Slit: This can be made up from two Gillette razor blades attached to a stout rectangle of sheet brass with an 8 mm. diam. hole drilled in the centre. Fig. 365 shows the method of mounting the slit on a $\frac{1}{4}''$ diam. brass rod provided with terminal nuts. If small bolts are used to secure the razor blades to the brass plate it will be found that the holes in the blades are large enough to allow for adjustment of the slit width.

The length of slit to use can best be found by experiment. It can be altered by pasting small strips of tin foil across the blades.

The slit used with the apparatus shown in Plate IVB was built up on the parallel-rule principle.

D. Achromatic lens: This lens, also the condenser, the lens F and prism G can be obtained from the firms mentioned in Chapter X [**218**].

A good method of mounting lenses is shown in fig. 366. M is a short length of brass telescope tubing of an internal diameter slightly greater than the diameter of the lens. The tube M is drilled and tapped with a ¼″ Whit. thread. Since the metal is thin, only a short length of thread can be cut in it. A piece of ¼″ diam. brass rod is screwed into the side of the tube and made tight by means of a bright steel back-nut N [**107**]. The joint between the nut and the tube is now soldered and any projection of the rod into the inside of the tube is filed away. The combination of thread, back-nut and solder makes a strong attachment. If the lens to be mounted has a strip of paper wound round it a good push-in fit can be obtained. Refinements of construction include a narrow internal ring of metal O cut from another piece of tubing and soldered to the inside of M for the lens to bed against. The use of paper can be avoided by fitting M with a small B.A. set screw.

E. Fig. 364, Diaphragm: This can be cut from sheet-brass or aluminium and mounted on a rod as shown for the slit in fig. 365. The diaphragm shown in Plate IVB was made from the back of a brass clock.

G. Fig. 364. Prism and grating: The grating should be bought mounted on a block of glass. To cement the block to the prism rest the prism in a rectangular hole cut in the lid of a box. Arrange the hypotenuse face upwards and horizontal. Pour about 1 c.c. of Canada balsam dissolved in xylol on to the face of the prism. Rest one edge of the glass block bearing the grating on the prism and gently lower it so that the balsam solution spreads out from the centre. The grating must face upwards and care must be taken to avoid any contamination of its delicate surface by the cement. The balsam takes about a fortnight to set. The process can be hastened by placing the prism and block in a hot airing cupboard. Any tendency for the block to slide sideways can be prevented by arranging large pins stuck in the box, round the outside of the block.

The prism, when completed, can rest on a flat table cut from a rectangular sheet of brass, this can be secured to a ¼″ diam. vertical brass rod by means of a back-nut [**107**].

The prism table shown in Plate IVB was made from the back of a brass clock.

To use the apparatus, adjust the lamp and condenser to give as brilliant and even illumination of the slit as possible.

Take the prism away and adjust the lenses D and F to form an image of the slit on a screen placed 3 to 6 feet away, at right angles to the optical axis. Replace the prism. A large, brilliant spectrum is formed on the screen. If colour filters are being examined it is worth noting that an image of the slit, the colour of the filter viewed by transmitted light, is formed in the direction S, fig. 364.

Apparatus for showing the interference colours of a soap-film on a screen. (Plate IVc, page 209.)

The optical arrangement is shown in fig. 367. Light from an ordinary 500 watt filament projection-lamp is concentrated by means of an optical lantern condenser, cooled by passing through a small tank of water and reflected on to a flat soap-film. Light from the film is again reflected and an image of the film is formed by a lens taken from an optical lantern. The film is made to rotate and get thinner and thinner, by means of an air blast. The beautiful changes of colour are repeated in regular order and just before breaking, the film can be seen to turn black.

An ordinary plano-convex lantern condenser can be suspended and adjusted by the arrangement shown in fig. 373.

A is a length of $\frac{3}{16}''$ diam. bright steel rod threaded $\frac{3}{16}''$ Whit. The lower end of the rod is fixed with two nuts to a $\frac{1}{2}''$ wide loop of thin brass made from strip metal or cut from a sheet, the ends being soldered. The condenser hangs vertically due to its own weight and can be adjusted for height by means of the terminal nut B.

The construction of a water tank and clip for holding it has been described in connection with a projection microscope, figs. 356, and 358.

A clip for holding and adjusting a mirror is shown in fig. 368. C1 and C2 are two strips of brass soldered to a $\frac{1}{4}''$ diam. brass rod B. This rod can pass through a slot cut in a vertical board as shown in Plate IVc. This arrangement enables the mirror to be rotated and slid backwards and forwards. Small strips of soft copper are soldered to the ends of C1 and C2 and are bent over to form clips for holding a plate-glass mirror.

The soap-film is formed across a 5·7 cm. diam. opening cut in a sheet of brass (Fig. 369), and soldered to the top of a brass funnel (Fig. 370).

The lower inside edge of this sheet of brass should be filed to a

knife edge as shown. A soap-film stretched across it will then keep flat.

The inside of the funnel should be painted a dull black. The writers used a brass funnel bought at a 6*d.* store and cutting off the stem, soldered the upper part to an elbow-bend of a speaking tube. This made a firm stand.

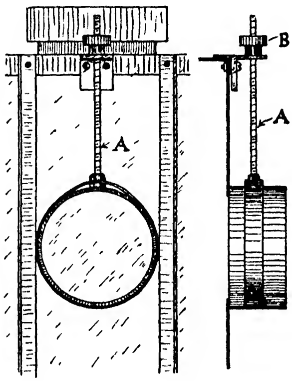


Fig. 373. Method of attaching a large condensing lens

The film is easily formed by dipping a celluloid set square into soap solution and drawing it across the opening in the funnel.

It is an advantage to wax the opening by dipping it into a bath of melted candle-wax.

An air blast is best directed from a glass tube drawn out to a small opening.

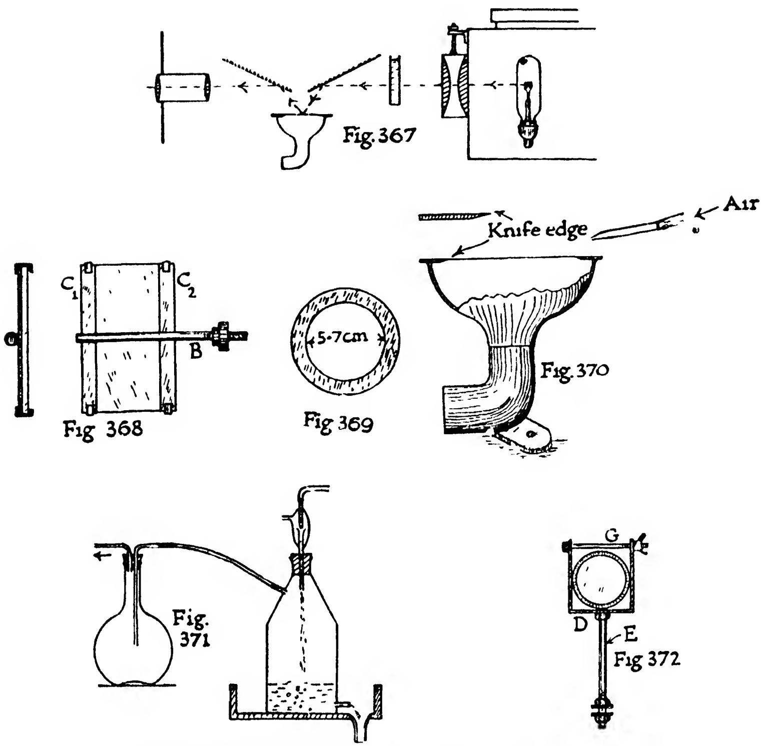
A method of obtaining a blast is shown in fig. 371. An ordinary filter pump is fixed in a rubber stopper and arranged to discharge water and air into a tin can. The can has two $\frac{3}{8}''$ diam. brass tubes soldered into it. Water escapes from the lower tube and air from the upper one.

It is best to pass the air supply through a litre flask. This helps to make the air-blast uniform and stops any spray.

A method of holding a projection lens is shown in fig. 372.

D is an inch wide strip of brass $\frac{3}{32}''$ thick. It is bent twice at right angles and secured to a $\frac{3}{8}''$ diam. vertical rod E with the help of a back-nut.

G is a length of $\frac{3}{16}''$ bright steel rod. A nut is securely tightened on to one end of this rod, if necessary the rod can be riveted over to prevent the nut coming unfastened. The other end of the rod, which passes through two holes drilled in the strip D, is fitted with



Apparatus for showing the interference colours of a soap-film on a screen

a butterfly or terminal nut. The vertical rod E is provided at its lower end with two nuts and washers and can slide in a gap between two lengths of $\frac{3}{8}''$ square section brass rod arranged to form a simple optical bench as shown in Plate IVc. A circular collar cut from a sheet of tin plate fits over the tube of the projection-lens and serves to cut out stray light.

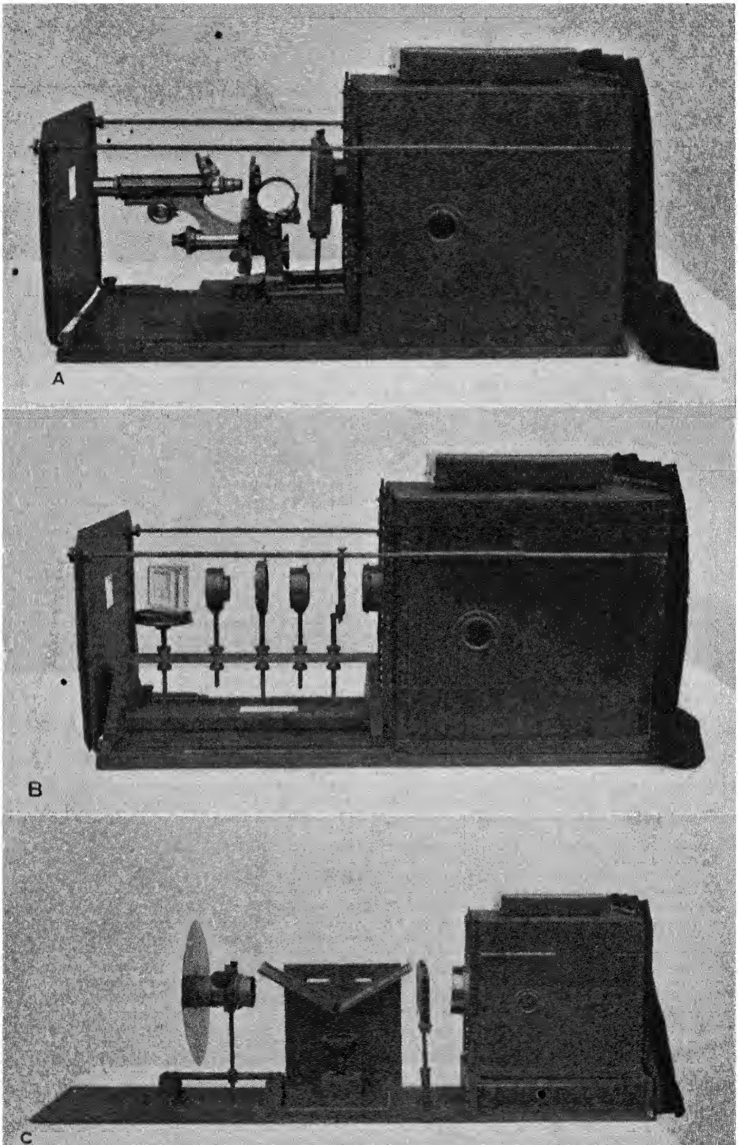
By connecting the tube of the funnel stand to a wireless loud speaker of the diaphragm type, it is possible to observe the vibration figures of the soap-film on a screen by causing the wireless set to oscillate.

Parallel-beam apparatus. (Figs. 374–376.)

With this apparatus it is possible to produce a bright parallel beam suitable for optical demonstrations to a large class by the grazing beam method.

A square section tube A, 2″ square 6″ long, is made from sheet brass [**74**]. A miniature lamp holder can slide in an opening cut at

PLATE IV



A. Projection microscope **B.** Spectrum projection apparatus
C. Soap film apparatus

B and can be fixed in position by screwing down the shade ring.

The right hand end of the tube is closed by a square plate C, fig. 375, with a circular hole. A double convex lens of about 4 cm. diam. and 10 cm. focal length is fixed over this hole and kept in position with four small clips. These clips can be made from short lengths of soft copper wire soldered to the plate and bent over the lens, or they can be made from strip brass and secured with nuts and bolts. A plate of brass, D, fig. 374, is held about 1″ in front of the lens. This has a slit cut in it measuring 3·5 cm. by 0·5 cm. The lamp used is a 12 volt, 36 watt gas-filled motor car

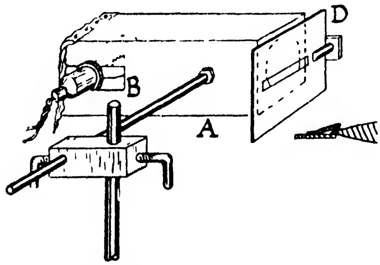


Fig. 374.

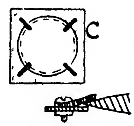


Fig 375.

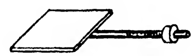
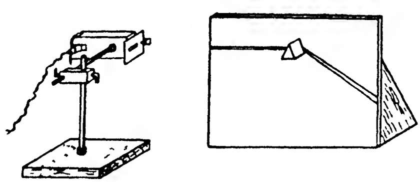


Fig 376.



Figs. 374-376. Parallel beam apparatus

head-lamp bulb with a filament arranged as a straight helix. The method of supporting the apparatus will be evident from the figures. It is well to arrange a curtain of black cloth at the lamp end of the tube.

To adjust the apparatus, place it to one side of a drawing board. This should be arranged in a vertical position and covered with a flat sheet of white card or paper.

Move the lamp holder towards and away from the lens until a bright parallel-sided track of light shows across the white surface.

It is important to rotate the lamp so that the wire supporting the filament is next to the curtain-end of the tube and is directly behind the filament as viewed from the lens-end. This avoids troublesome stray reflection. For the same reason the inside of the tube should be painted dull black.

Glass blocks and prisms can be supported on the front of the

board by resting them on a small table made by soldering a strip of brass to a $\frac{1}{4}''$ diam. brass rod (Fig. 376).

The rod has a $\frac{1}{4}''$ Whit. thread cut on it and passing through a hole in the board can be secured with a terminal nut from the back.

The track of light through glass blocks and prisms can be made visible by slight grinding of the back surface. This is easily carried out by rubbing the surface on a sheet of oiled emery cloth. The lamp can be tilted and the light directed into a glass-sided tank of water to show refraction and total reflection. A little fluorescein should be added to the water to make the light visible and chalk from a duster or hydrochloric acid and ammonia fumes can be used for the air.

Apparatus for demonstrating the intermittent illumination of a neon lamp operated from an alternating current supply. (Figs. 378 to 381.)

If a neon lamp of the Osglim type is placed in a holder connected by a flexible cable to an alternating current supply and is whirled round in a circle it appears as indicated in fig. 377.

It is of interest to observe the effect of speed of rotation on the number of patches of light that become visible and for this purpose it is more convenient to rotate the lamp with a machine than by hand.

An easily made whirling arrangement is shown in figs. 378 and 379.

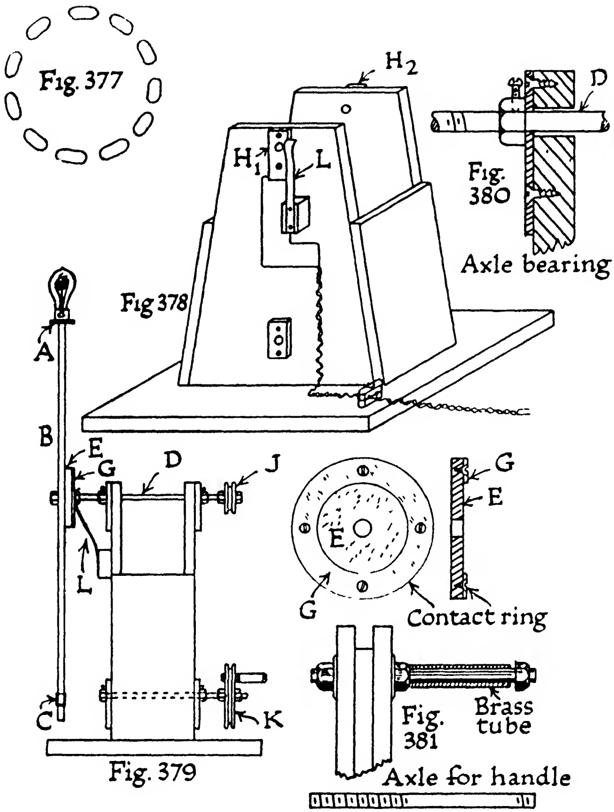
A neon lamp is arranged in a batten-type lamp-holder screwed to the end of a wooden lath measuring $2' \times 2'' \times \frac{1}{2}''$. This lath is secured to an axle driven by a cord passing over a pulley.

Current is conveyed by means of the axle bearings and by a slip ring attached to the lath.

A. Fig. 379. Batten type lamp holder: An extra hole should be drilled in the base plate so that the latter can be screwed to the lath in a symmetrical position.

B. Wooden lath: A $\frac{3}{16}''$ diam. hole is drilled at the centre and tapped with a $\frac{1}{4}''$ Whit. tap. A strip of sheet lead is wound round the end at C to act as a counterweight. This can be secured with a $\frac{3}{16}''$ nut and bolt.

D. Axle made of $\frac{1}{4}''$ diam. bright drawn mild steel. A $\frac{1}{4}''$ Whit. thread is cut on each end of this rod to a distance of about 2″, but not so far as to bring the threaded part in contact with the bearings.



Figs. 377–381. Neon lamp rotator

E. A disc of wood $2\frac{1}{4}''$ diam., screwed to the lath and held firm with a nut.

G. A disc of brass or copper $2\frac{1}{4}''$ diam. screwed to the wooden disc. This has a $1\frac{1}{4}''$ diam. central hole and care must be taken to avoid a short circuit between the axle and the disc.

H1 & H2. Fig. 378. Bearings made of strip-brass $2'' \times 1'' \times \frac{1}{8}''$. The central hole should be drilled with a $\frac{1}{4}''$ drill and if necessary carefully enlarged with a broach to such a size that a piece of $\frac{1}{4}''$ diam. axle-rod will turn in it without binding. When testing for fit use a piece of unthreaded axle rod that has had the end bevelled to remove any burr.

One effect of cutting a thread on a rod is to cause a slight increase in the diameter and before the axle D that has been threaded at each end can be passed through the bearings it

may be necessary to subject the threaded portion to a little filing.

The bearings are attached to the wooden framework with ordinary wood-screws.

Provision must be made to prevent the axle moving sideways, this can be done by drilling two $\frac{1}{4}''$ Whit. bright steel nuts or brass terminal nuts with a $\frac{1}{4}''$ drill, to cut away the thread. These nuts are drilled and tapped at the side and each one is provided with an $\frac{1}{8}''$ Whit. screw to serve as a set-screw for fixing it to the axle (Fig. 380).

J. Axle-Pulley. Fig. 379. This can be made from a cotton reel with a groove filed in it by means of a round file or it can be built up of three discs of three-ply wood. It is fixed on the threaded portion of the axle by means of two nuts. If the pulley tends to slip on the axle, place split washers under the nuts instead of ordinary washers.

K. Driving-Pulley. This can be built up of three discs of three-ply wood. A handle is attached as shown in fig. 381. The arrangement of the axle and bearings for the driving pulley is similar to the top axle and set of bearings. Nuts that have been drilled out and provided with set screws are used to prevent side play.

L. Figs. 378 and 379. A contact formed from a strip of hard, springy brass. A strip of ordinary hard, rolled sheet brass can be rendered sufficiently springy by hammering it on an anvil.

One wire from the lamp holder is connected to the axle D and the other to the brass disc G. Connections from the main are made, one to the contact L and the other to the bearing H1 of the top axle.

An excellent driving-band can be made from curtain rod of the expanding spring type. Cut a suitable length and join it into an endless band as follows. Cut off the screw portion of one of the small steel hooks supplied with the rod and screw half of this length into one end of the rod.

Grip this end and at the same time give the other end two or three turns in an anti-clockwise direction. Bring the twisted end into mesh with the projecting portion of the screw and allow the rod to untwist and thread itself on.

Apparatus for demonstrating electrification produced by the friction of falling sand on a metal wire. (Fig. 382.)

A. A square board with a hole cut in it to take a glass funnel.

B. Silk cords to insulate the board. Artificial silk is not suitable.

C. Top board. This is a little larger than the lower one.

D. A copper wire. This is buried in the sand and extends nearly to the end of the funnel.

E. An electroscope. Good results can always be obtained by using an insulating stopper made of sulphur.

A sulphur stopper can be cast in a mould made of waxed paper or cardboard.

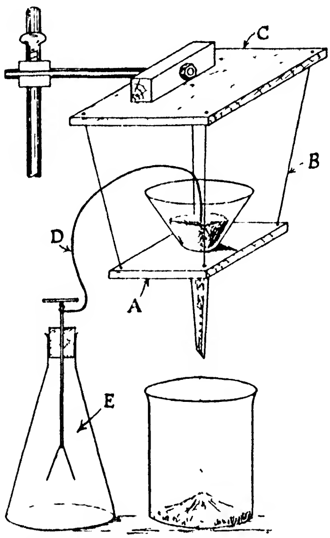


Fig. 382. Electrification apparatus

The sand used for the experiment should be heated on a tin plate before pouring it into the funnel. The electroscope becomes charged as the sand runs out of the funnel and rubs the wire.

A switch. (Fig. 383.)

An effective switch of low resistance can be made as shown in fig. 383.

A strip of brass is cut, drilled, sawn in half and the portions are screwed to a wooden base [**54**–**58**].

A post for a brass terminal nut passes through the centre of the block. The post is made of $\frac{1}{4}''$ mild steel rod threaded $\frac{1}{4}''$ Whit. and screwed into a hole drilled in the wood [**93**]. The wood is drilled with a $\frac{3}{16}''$ drill and tapped $\frac{1}{4}''$ Whit. [**113**]. Screw the wood on to the rod until it comes tight against the unthreaded

part of the metal. Saw the rod across the dotted line AB, and file the small projecting portion of metal flush with the wood [84]. A terminal can be made from a brass, round headed wood-screw

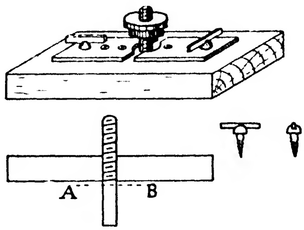


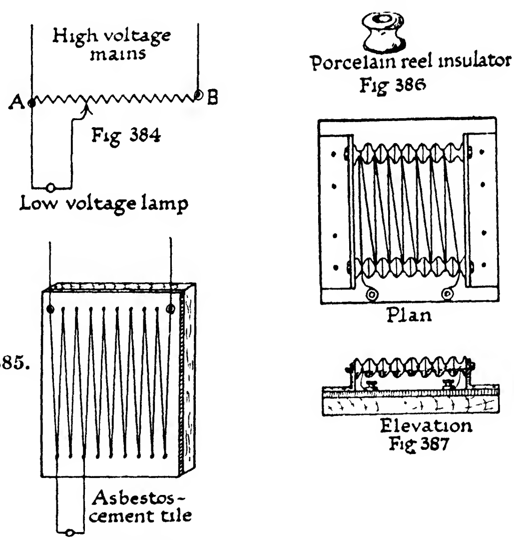
Fig. 383. A switch

by soldering a cross-piece strip of brass or half a washer into the screw-driver slot, previously enlarged with a warding file [145].

Electrical resistances. (Figs. 384–387.)

Motor-car headlamp bulbs with straight and concentrated filaments, working at 6–12 volts, are particularly useful for ray track

Fig. 385.



Figs. 384–387. Electrical resistances

and diffraction experiments and for reflecting galvanometers, they can be worked from 50–230 volt mains by means of a resistance arranged as a potentiometer, fig. 384. On a 230 volt supply 11′ of No. 22, S.W.G. nickel-chromium alloy wire makes a suitable resistance wire AB. By starting at A and taking tappings from

A towards B it is possible to obtain any voltage from 0 to 230. The resistance wire gets hot when in use and it is advisable to arrange it zig-zag fashion on a wooden baseboard covered with a piece of asbestos-cement sheet, fig. 385 [207]. The wire can be spaced between two terminals and two rows of round headed screws. Instead of nickel-chromium wire it is possible to use expanding spring curtain rod, 2–4 yds., according to the voltage. The nickel-chromium wire is best since its temperature co-efficient is small and the tapping point remains quite constant during use.

Arc-lamp and other high resistances can be made for a few shillings by the use of nickel-alloy resistance-wire.

Henry Wiggin & Co., Ltd., Thames House, Millbank, London, S.W.1, manufacture a wide range of such wires and issue complete technical data.

Brightray, a nickel-chromium alloy, has a specific resistance of 103 microhms per cm. cube and can be worked at a red heat. Ferry, a nickel-copper alloy, for use at a black heat, has a specific resistance of 48 microhms per cm. cube and a temperature co-efficient which is practically zero.

A convenient method of spacing a resistance wire either straight or spiralled is to use small white porcelain reel insulators of the type shown in fig. 386.

The General Electric Co., Ltd., manufactures reels, diam. $\frac{5}{8}''$, height $\frac{1}{2}''$, diam. of hole $\frac{5}{32}''$. They can be purchased from electricians for 6*d.* a dozen and can be threaded on $\frac{1}{8}''$ diam. steel rods fitted in a strip steel framework or between two pieces of angle steel attached to a baseboard, as shown in fig. 387.

A large direct current electro-magnet. (Figs. 388–394 and Plate VA.)

The construction of a large magnet can best be carried out with the help of a lathe and a planing machine. The owners of hand-tools only should not be deterred from its construction since the necessary machining could be entrusted to a local or other firm of engineers.[1]

The poles and yoke of the magnet are made of mild steel. Each pole measures 10″ long and 2″ in diam. and the yoke $9\frac{1}{2}'' \times 4'' \times 1''$ (Fig. 388). The poles are tapped $\frac{1}{2}''$ Whit. to a depth of $1\frac{3}{4}''$ and attached to the yoke with $2\frac{1}{2}'' \times \frac{1}{2}''$ Whit. steel bolts. A large spanner must be used to make these bolts as tight as possible. The ends of the poles and the top surface of the yoke should be machined flat, so that the air gap is reduced to a minimum.

[1] Stuart Turner Ltd., Henley-on-Thames, England, make castings and do machining to private orders.

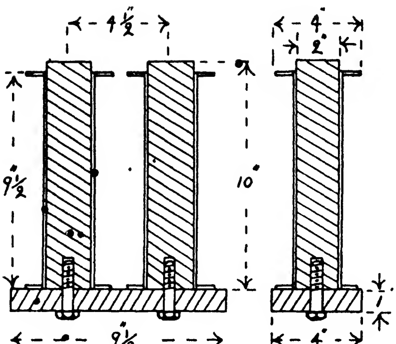


Fig. 388

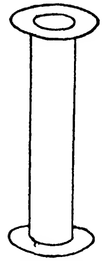


Fig 389

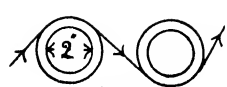


Fig. 390

A large direct current electro-magnet

The bobbins, fig. 389 with an 1″ wide flange can be made of sheet brass or copper, the bobbin ends being brazed or soldered to the tube portion [**68, 78, 130**]. A set of loose pole-pieces with square and pointed ends can be made of 2″ square mild steel. One side face of each of these pole-pieces should be planed flat to make good surface contact with the pole ends.

The surface of the bobbins exposed to the winding should be given a coat of Robbialac enamel for insulation purposes.

One flange of each bobbin has a ¼″ diam. hole drilled close to the junction with the tube part. This serves as a leading-out place for the winding which at this point should be protected by a short length of rubber tubing or insulated sleeving as sold at wireless shops.

Each bobbin is filled with No. 16 D.C.C. copper wire. It is best and cheaper to buy this on a drum than in 1lb. lots. About 35lbs. of wire is necessary and this is the chief expense associated with the construction. The winding of the wire can be carried out by hand.

The ends of the wire are brought to a terminal block and connected in series with a switch, so the current circulates through the coils in opposite directions, fig. 390. A good finish is obtained by covering the windings with black velveteen. The magnet takes about 3 ampères at 20 volts. Many experiments can be carried out with a large magnet of this type.

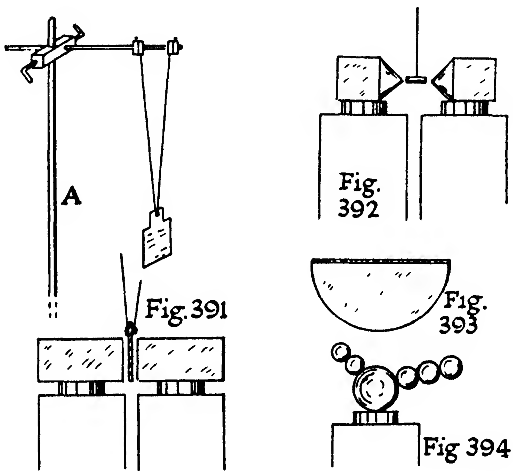
Fig. 391. A plate of copper suspended by two thick copper wires from a horizontal support. The plate can swing like a pendulum. The rod A is 2′ long and can be screwed into the baseboard [**113**]. The plate is adjusted to swing between the square pole-pieces and immediately comes to rest when the magnetising current is switched on [**85, 102, 104, 105**].

Fig. 392. A short length of bismuth suspended by a fine silk thread between the pointed pole-pieces to demonstrate diamagnetism.

A strip of bismuth can be prepared by melting some pure bismuth crystals in a hard glass test-tube, and inclining the tube during solidification of the contents.

Fig. 393. A plate of aluminium. If this be allowed to fall between the gap of the square pole-pieces it slowly sinks down as though passing through a very viscous liquid [6].

Fig. 394. Steel balls, large and small, held in position by the magnetising force.



Figs. 391–394.

An ammeter placed in the circuit shows the slow growth of the current due to self induction.

A lifting electro-magnet. (Figs. 319–324 (Ch. X) and Figs. 395–397. Plate VB, page 223.)

This can be made from a piece of mild steel shafting and supplied with current from a miniature 3½ volt pocket flash lamp battery and will support a weight of 30lbs.

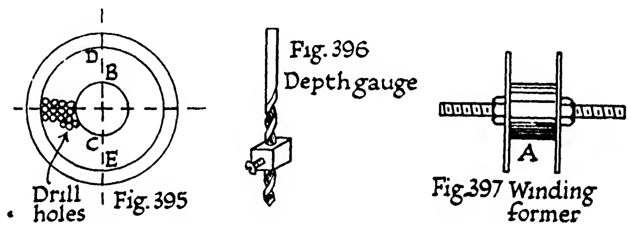
The groove for the winding is easily made by turning in a lathe (see note on page 213 on lathe work in connection with a large D.C. electro-magnet). A hand method of construction is to drill out numerous holes, all to the same depth, and chip away the remaining metal with the help of a hammer and a small cold chisel, fig. 395.

A small block of metal attached to the drill as shown in fig. 396 can be used as a depth gauge.

Fig. 397 shows the former used for making the winding. A is a piece of broom-stick carefully cut to have a length about $\frac{1}{32}''$ less than the depth of the winding groove and of a diameter about $\frac{1}{32}''$ greater than that of the central pole BC of the magnet.

It is fitted with an axle made of a short length of $\frac{1}{4}''$ steel rod and provided with two nuts and end-discs of sheet metal of a diameter $\frac{1}{32}''$ less than the outside diameter DE of the winding space cut in the magnet. The edges of the discs should be made smooth.

The inside faces of the end-discs and the piece of broom-stick should be covered with paper and painted with melted candle wax. The former is then filled with No. 28 D.C.C. copper wire. The winding can be carried out by hand with the axle of the former gripped and rotated in the chuck of a hand drill.



A lifting electro-magnet. Details of construction

The drill should be clamped in a horizontal position in a vice and the spool of wire provided with a temporary axle. The starting end of the wire can be brought out through a hole drilled in one of the discs. Guide the windings into position and pour melted candle wax over every two layers. When the winding is completed, allow the wax to go quite hard, then unfasten the nuts, remove the end faces and push the coil off the broom-stick. The paper prevents adhesion. Fasten some fine thread through the centre hole of the coil to prevent the wire from coming undone. Thread the ends of the wire through holes drilled in the magnet block; the wire at these places should be protected with insulated sleeving or valve tube rubber. Push the coil into position and fill up the spare space with melted wax. Allow the wax to set hard, then level off flush with the pole faces.

An ordinary flat iron makes a very good keeper for a magnet of this type. Extra weights can be suspended from the handle of the iron. A strong handle for supporting the magnet can be made of plaited boot-laces passed through the top knob.

Elihu Thomson alternating current repulsion magnet. (Figs. 398–406.) The core of the magnet is made of 12″ lengths of soft iron faggot binding wire. This is sold in coils by ironmongers. Suitable lengths of wire should be cut, made as straight as possible then bound together with insulating tape. Electric bell wire can be used for winding the magnet. For direct connection to a 200 volt supply the core should be wound for 11½″ with two layers of wire and for 7½″ with five more layers. The magnet can be mounted in a wooden framework as shown in fig. 398 and connection made to the A.C. mains through a switch, plug and socket.

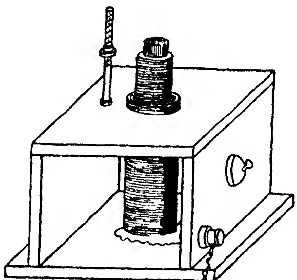


Fig. 398

Fig 399

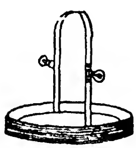


Fig. 400

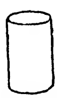


Fig. 401

Fig 402

Fig 403

Fig. 404

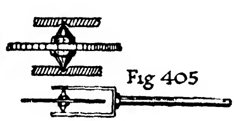


Fig 405

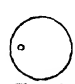


Fig. 406

Figs. 398–406. Elihu Thomson alternating current repulsion magnet

Fig. 399 is a ring of 5–6 turns of No. 16 bare copper wire. This should have an inside diameter about ¼″ greater than the coil measured across the 2-layer part. The wire can be wound round a bottle of suitable diameter, then slipped off, and made into a solid ring of low resistance by running solder between the turns.

If this ring be placed over the magnet it will be thrown into the air with considerable force on turning on the current.

Fig. 400 is a coil of No. 22 D.C.C. wire wound on a 5″ diam. framework of strip brass. The ends of the wire are connected to two $3\frac{1}{2}$ volt electric lamps arranged in series. The lamps can be fitted in miniature holders attached to a strip brass handle.

On lowering the coil over the magnet lamps light up the brilliantly.

The length of wire to use can best be found by experiment. About 30 turns is usually sufficient.

Fig. 401 is a tube of brass or copper. This tends to float and gets very hot when placed round the magnet. The same or a similar tube when slit with snips does not show this effect.

Fig. 402 is a coil of four turns of thick copper wire that can be placed round the magnet. A fine copper wire connected to the ends can be fused by the current generated in the thick winding.

Fig. 403 is a coil of No. 22 D.C.C. copper wire with the ends joined to a $3\frac{1}{2}$ volt lamp. The coil is soaked in candle wax. The lamp and coil can be put in a beaker of water and when held over the magnet the lamp will light up.

Fig. 404 is a coil of wire wound on a cardboard or fibre tube and connected to a telephone receiver.

If the coil be placed over the magnet a loud hum is produced in the receiver.

Fig. 405 is a 4″ diameter disc of aluminium about $\frac{1}{16}$″ thick provided with a pivot made from a short length of $\frac{1}{8}$″ diam. threaded steel rod, or a steel screw. The ends of the rod can be ground to a point on a carborundum wheel. The pivot is mounted between centre punch impressions made in a strip of brass, bent as shown and provided with a handle.

Another disc of aluminium, Fig. 406, for preference about $\frac{1}{8}$″ thick is mounted on the $\frac{1}{4}$″ diam. vertical steel rod shown in Fig. 398 and kept in position with two nuts. This disc is $3\frac{1}{2}$″ in diameter and should be arranged to about half cover the top of the iron core of the magnet. The $\frac{1}{8}$″ disc rotates when held over the shaded iron core.

Electro-magnetic dip-needle. (Fig. 407 and Plate Vc.)

A rod B, 9″ long, of $\frac{1}{4}$″ diam. mild steel, passes through and is soldered into a short length, A, of $\frac{1}{2}$″ square-section brass tube.

C and C1 are 1″ lengths of bicycle spoke, threaded 9 B.A., and soldered or screwed into holes drilled in the ends of B [**14**].

The rod B is wound in the same direction throughout its length with 4 layers of No. 24 D.C.C. wire.

The ends of the wire are soldered to needles D and D1 driven into the centre of square plugs of wood fitting in the ends of A [**90**].

A third length of threaded spoke, E, is attached to the lower face of the square brass tube. The needles serve as an axle and rest on two plates F and F1 of thin brass.

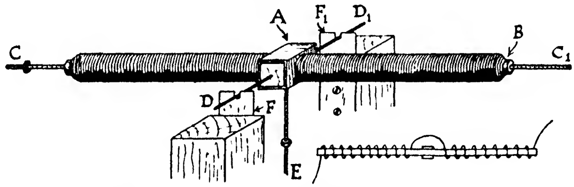


Fig. 407. Electro-magnetic dip-needle

Current is supplied from a 4–6 volt accumulator through the plates and the needles. Care must be taken that the latter are not pushed in so far as to short circuit on to the steel rod B. The rod is balanced – in a horizontal position – with the help of small nuts threaded on to the lengths of spoke. When the current is switched on the rod tilts to approximately the angle of dip, if set in the correct position with reference to the magnetic meridian.

On turning off the current the rod returns to a horizontal position.

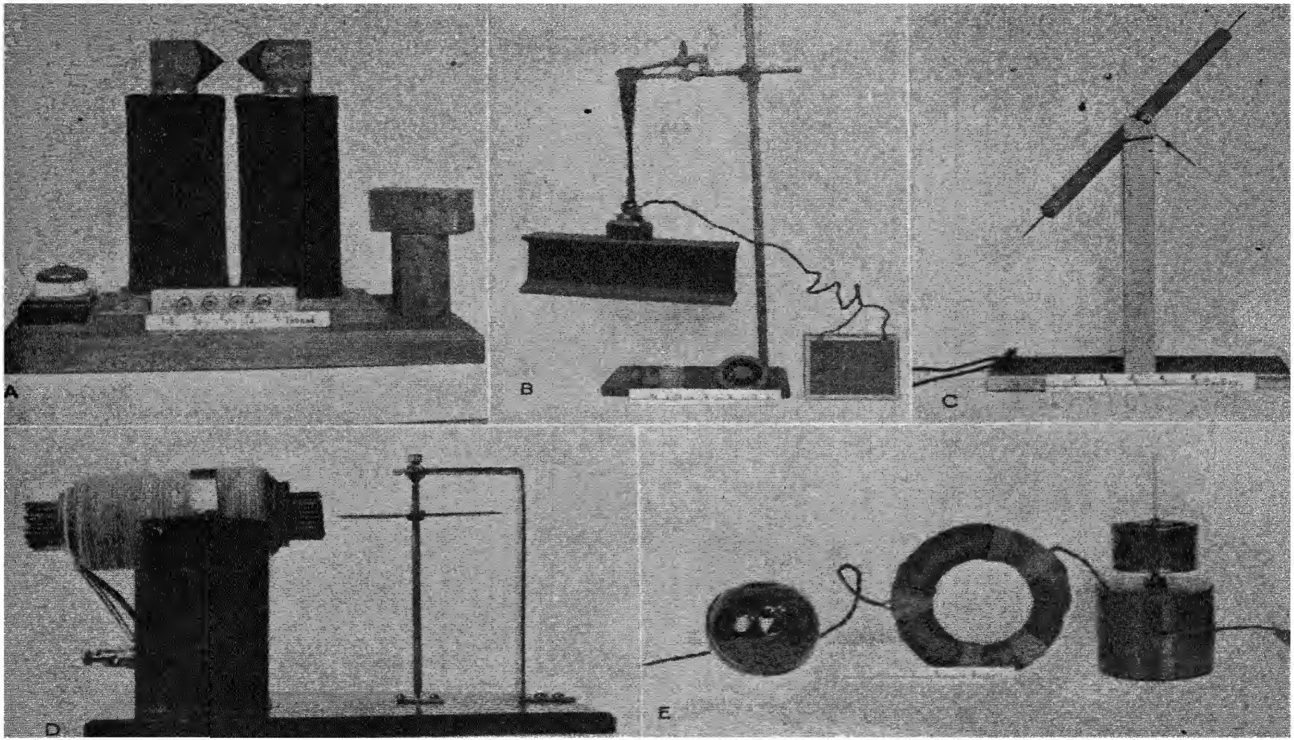
A synchronous motor. (Plate VD.)

This is of interest in connection with the development of electric clocks worked from A.C. mains.

The chief components are an A.C. magnet and a rotor made from a 2½″ length of hack-saw blade which has been magnetized. The portion of magnetized blade is mounted on a spindle. The motor is not self-starting, the spindle has to be given a twist between a finger and thumb, but once brought into step with the magnetic field will continue to rotate.

The magnet core is a 1″ diam. bundle of 4¼″ lengths of soft iron faggot binding wire. This wire can be bound with insulating tape or packed into a cardboard tube to keep the lengths together. For a winding 8 layers of No. 22 D.C.C. wire can be used and this is suitable for connection to the 12-volt tapping of a transformer or potentiometer. Before the hack-saw blade can be drilled it must be softened by making it red hot. After drilling it should again be

PLATE V



A. A large direct current electro-magnet B. A lifting electro-magnet C. Electro-magnetic dip-needle
D. A synchronous motor E. Apparatus for producing a rotating magnetic field

made red hot and hardened before magnetizing by plunging it, red hot, into cold water. A simple way of magnetizing is to wind insulated wire round the strip of blade and pass a current through the wire from a 6–12 volt accumulator. A car starting accumulator can be used.

The balance-wheel pivots of old alarm clocks make good bearings.

Apparatus for producing a rotating magnetic field. (Figs. 408–410. Plate VE.)

This apparatus can be used to demonstrate the action of an induction motor and is worked from a single phase supply of alternating current.

The centre core C is made of soft iron faggot binding wire to be bought from an ironmonger. The wire is wound about a Winchester bottle and sufficient wire put on, so that when slipped off the bottle a ring of $\frac{3}{4}''$–1″ diam. is formed. The iron wire should be wound with insulating tape to keep the coils in position.

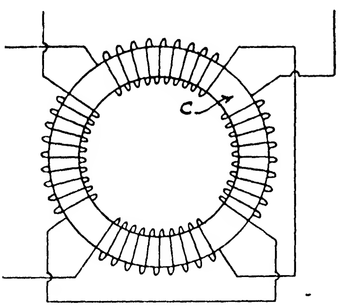


Fig. 408.

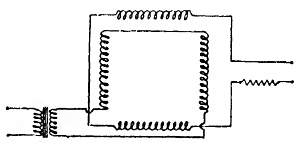


Fig. 409.

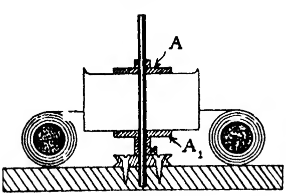


Fig. 410.

Apparatus for producing a rotating magnetic field

The electrical winding consists of four coils, each of about 5 layers of electric bell wire. These coils are all wound in the same direction and opposite pairs are connected together as shown in Figs. 408 and 409. One set of coils is joined to the secondary of a transformer with an output at about 25–30 volts. If such a transformer is not available, one with a higher secondary voltage can

be used, but in this case a resistance should be included in the secondary circuit to bring the potential difference of the supply at the coil terminals down to 25 volts.

The second set of coils is connected through a resistance to the main supply. The resistance should be adjusted to give a potential difference at the coil terminals of about 25 volts.

Fig. 410 shows a sectional view of a tin can free to rotate on a fixed vertical axle. The can will rotate at a high speed when placed inside the ring.

A $\frac{3}{16}''$ diam. hole is drilled in the centre of the lid and the base of the can.

Two Meccano flanged wheels are soldered to the can as shown at A and A1 and provide good bearings. The axle is fixed to another wheel that is screwed to the baseboard.

A copper ball, the ball of a plumber's ball valve, makes a good object for rotation. A good bearing can be provided by passing a piece of brass tubing through the centre and soldering the tube at the points of emergence.

It is interesting to study the magnetic field of the ring by placing within it a porcelain basin containing iron filings or by sprinkling filings on to a sheet of glass placed in a horizontal position over the ring.

CHAPTER XII

MORE APPARATUS DESIGNS

Apparatus with vibrating string illustrating the theory of polarisation. (Figs. 411–416.)

THIS apparatus provides for a beautiful demonstration of the action of Nicol prisms and of phenomena connected with the vibration of a stretched cord.

Movement is given to one end of a string by means of an eccentric mechanism driven by an electric motor, A, fig. 411. Two slots are provided one at B and another at C. These slots can be turned into a vertical or horizontal position. D is a support and clamp to allow for the adjustment of the string. A suitable length of string is 8′. The correct tension can be quickly found by experiment.

As shown in the figure the string has a vertical and horizontal component between A and B. The slot B filters out the horizontal component, and if C be placed in a horizontal position the string between C and D will remain at rest. On turning slot C into a vertical position the string section CD will begin to vibrate, but will stop when slot B is made horizontal.

With slots C and B removed or pushed to one side the vibrating string can be used to demonstrate the effect of tension on the number of nodal points.

An electric fan motor can be used to drive the string. The eccentric mechanism is shown in fig. 412.

E. Eccentric arm: Made of strip brass, $\frac{1}{2}'' \times \frac{1}{8}''$, and about $4\frac{1}{2}''$ long. This arm works on two pivots F and G [**54–57**].

F, G and H. Pivots: Made of bolts $\frac{3}{4}''$ long, No. 2 B.A. or $\frac{3}{16}''$ Whit. The bolts pass through holes drilled in the eccentric arms and are secured with nuts as shown in fig. 413, a side elevation of the pivot at F. The fan of the motor is removed and a face plate is fitted on the axle.

I. Face plate: A Meccano face plate No. 109 can be used or a plate can be constructed from a disc of sheet brass soldered to a brass terminal nut provided with a set-screw (Fig. 414).

J. Fig. 412. Eccentric arm, similar to E but $8\frac{3}{4}''$ long. The

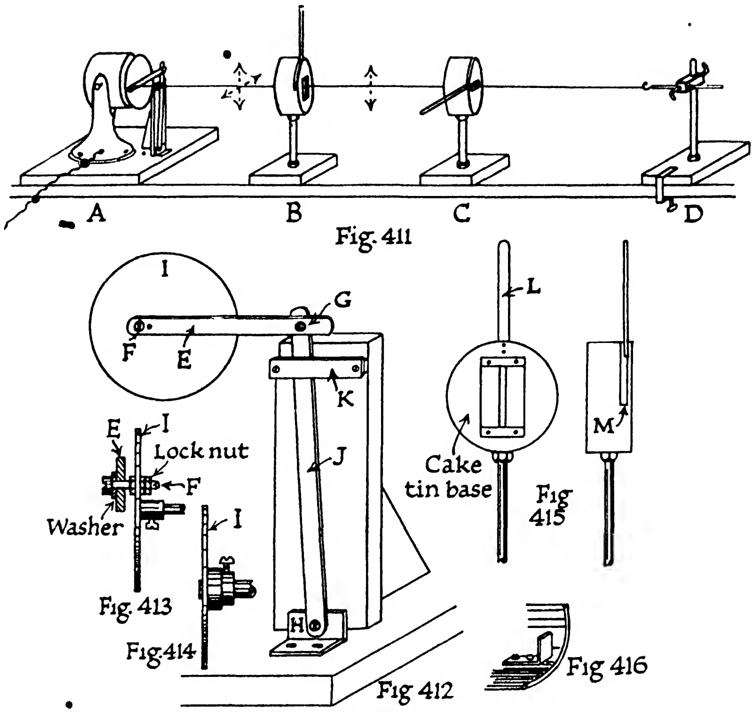


Fig. 411. Apparatus with vibrating string, illustrating the theory of polarisation (Figs. 412–416. Detail)

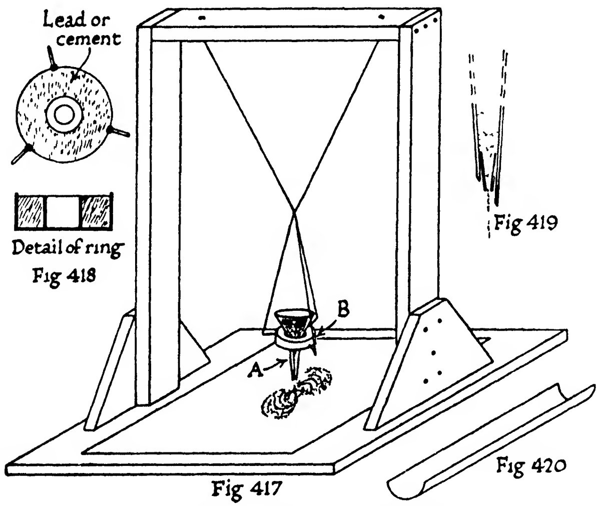
length of the eccentric arms can be varied to suit the motor. The lower end of J works on a pivot secured to a plate of angle brass H [87].

K. Guide: This is made of $\frac{1}{2}'' \times \frac{1}{8}''$ strip brass and gives support to the upper end of eccentric arm J. It is fastened with screws to a vertical wooden post. The screws are provided with distance pieces, so that a gap is formed between the guide and the wooden post.

A hole for the string is drilled in the eccentric arm E close to the pivot F. The string is secured with a knot at the back. The distance of the pivot F to the centre of the face plate is 2 cm. and the distance of the string hole to the centre is a little less than this.

B & C, fig. 411, Slots: These can be prepared from 5″ diam. cake tins of the type with removable bases. A slot $2\frac{1}{2}''$ long and $\frac{1}{2}''$ wide is cut in each of the bases. This has sharp edges and would soon fray the vibrating string. A slot about $\frac{1}{8}''$ wide and $2\frac{1}{4}''$ long is therefore formed of strip brass secured

with nuts and bolts around the slot cut in the base (Fig. 415). An arm L is fastened to the base and passes through a slot M cut in the side of the cake tin. This slot must be long enough to enable the arm to be turned from a vertical to a horizontal position. Two strips of brass, bent as shown in fig. 416, are fixed inside the tin to serve as guides to the loose base and prevent the latter from working out of position.



Figs. 417-420. A sand-figure pendulum

The tins are mounted on posts made from $\frac{3}{8}''$ steel rod attached to wooden baseboards [93, 113].

The components of the string tensioning clamp and support at D, fig. 411, have been described in connection with other apparatus [85, 102–105].

A sand-figure pendulum. (Figs. 417–420.)

A funnel containing sand is suspended as shown. The funnel can be drawn to one side, then allowed to swing free. The motion of the funnel is complex, but rhythmical. Sand runs out of the funnel and builds up a complicated design on a sheet of black card.

A. Glass funnel and sand: Fine white sand is the best to use. It should be quite dry and passed through a fine gauze sieve to remove all lumps.

B. Ring: This ring should be made of heavy material. The outer steel ring of an old ball race from a motor lorry can be

used. A ring can be made by filling the lid of a large tin can with lead or cement. A hole should be drilled in the bottom of the lid to allow the stem of the funnel to pass through, and space for the upper part of the funnel is provided by placing a short length of 1¼″ diam. brassed curtain tubing round the hole to preserve a space free of lead or cement [**18**]. Three 1″ lengths of cycle spoke arranged at 120° intervals are soldered or otherwise attached to the outside of the ring, see fig. 418 [**14**].

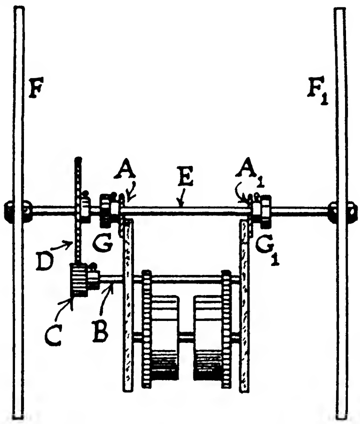


Fig. 421. Mechanism of a model motor-driven garden roller

The ring is suspended with fine string from a wooden framework. A good size for the framework is 30″ high and 20″ wide. The sand patterns can be modified by changing the length proportions of the upper and lower strings. To obtain well-formed patterns the distance from the end of the funnel to the centre of the paper should not exceed ½″ and a fine stream of sand is obtained by fitting a short length of drawn out glass tubing into the stem of the funnel (Fig. 419). A piece of card painted black forms a good background for white sand. When the pattern is finished the card can be removed and the sand tilted into a trough-shaped piece of tin plate (Fig. 420). This enables the sand to be easily replaced in the funnel.

Model to demonstrate the mechanics of a motor-driven garden roller. (Fig. 421 and Plate VIA, page 235.)

The motive power is an old gramophone motor. These can be bought second-hand for about 2/6 from most gramophone repair shops.

The motor is arranged to hang from the axle of the roller and causes the latter to roll along a floor or smooth road at a fast walking pace (Fig. 421).

A & A1. Roller axle-bearings: With the particular motor used it was found necessary to extend the side plates of the mechanism to form bearings and at the same time to provide room for the meshing of an extra gear wheel and pinion. The extension was carried out with strips of brass [**54–57**].

B. The turn-table axle of the motor.

C. Pinion wheel: Meccano pinion wheel No. 25, $\frac{3}{4}''$ diam. The hole in the wheel must be drilled out to the diameter of B.

D. Gear wheel: Meccano gear wheel No. 27.

E. Roller axle: Made of $\frac{1}{4}''$ diam. steel rod.

The axle hole in the Meccano gear wheel No. 27 is not large enough to take $\frac{1}{4}''$ diam. rod. The difficulty can be overcome by removing the bearing of a No. 27 wheel and soldering on a new one made from a $\frac{1}{4}''$ Whit. brass terminal nut that has been drilled out to $\frac{1}{4}''$ and provided with a $\frac{1}{8}''$ Whit. thread set-screw to secure it to the axle.

The bearings A and A1 are provided with $\frac{1}{4}''$ diam. axle holes.

F & F1. Roller side-plates: Cut from 3-ply wood and held between nuts threaded on the axle.

G & G1. Collars: These are attached to the axle E and prevent side movement of the motor. They can be made from $\frac{1}{4}''$ Whit. brass terminal nuts, and are provided with set-screws, $\frac{1}{8}''$ Whit. The centre hole of each nut is drilled out to $\frac{1}{4}''$ diam.

A pump for filling rubber balloons with coal gas. (Fig. 422.)

An ordinary bicycle pump can be modified to make it suitable for filling toy rubber balloons. The latter can be used for buoyancy experiments.

Fig. 422 shows the necessary changes.

A. Nipple: This is a non-return nipple as used for filling football bladders. Nipples for screwing into bicycle pumps are supplied for a few pence by sports equipment and cycle dealers.

B. Side tube: This is a 2″ length of $\frac{1}{4}''$ diam. copper tube. The tube is soldered into a hole drilled in the side of the pump. A secure attachment is obtained by passing the tube through a $\frac{1}{4}''$ brass terminal nut that has had the thread cut out with a

¼″ drill. The face of the nut, next to the pump barrel, should be filed to the curve of the barrel with a half-round file. This gives a good surface for soldering.

Any rough edges or projection of the tube or solder on the inside of the barrel should be removed with a round file.

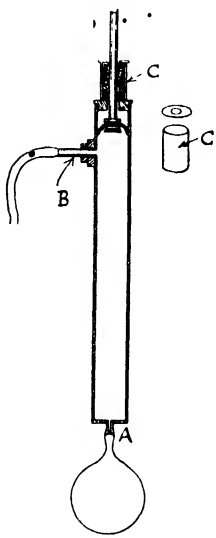


Fig. 422. A pump for filling rubber balloons with coal gas

C. Packing gland: This is made from a 1½″ length of ½″ or ⅝″ diam. brass tube. The bottom edge of the tube is soldered to the top of the barrel. A woollen thread, soaked in thick oil, is wound round the plunger of the pump and well packed into the brass tube to form an air-tight gland. When the tube has been filled with packing a circular cover is soldered on to keep the packing in position.

The extra side drawing shows the tube and cover before soldering in position.

To use the apparatus: Attach the side tube to a coal-gas supply, and work the plunger once or twice to drive out the air. Pull the plunger to the top of its stroke, leave the gas turned on. Expand a new balloon with air. Allow the air to escape and flatten the balloon to drive out as much air as possible. Slip the inlet tube of the balloon over the nipple and work the pump. A cluster of balloons filled with coal-gas can be attached to a cotton thread and sent as captives to a great height.

Aeration apparatus for a bell-jar aquarium. (Fig. 423.)

Apparatus of this type is used at the Marine Biological Laboratory, Plymouth, for the aeration of bell-jars containing plankton.

A copper tube A is bent as shown and soldered into the base of a tin can [**143**].

The can, arranged under a water supply, is suspended from the end of a pivoted wooden lath. The long arm of the lath is connected to a glass plate suspended in the bell-jar by means of a fine cord passing over pulleys. The can fills with water causing the lath to tilt and the plate to sink.

When the water fills the bend of the tube the latter acts as a siphon and causes the tin to empty. The tin then rises, ready for the cycle of action to be repeated. The slow, but constant

movement of the glass plate provides for surface aeration of the water throughout the jar.

B. Pivot: Made from Meccano parts. A bush wheel Meccano part No. 24 is screwed to the side of the lath to form an attachment for an axle. Bearings can be made of strip brass.

C. Counterweight: A strip of sheet-lead.
This can be moved along the lath and provides for adjustment.

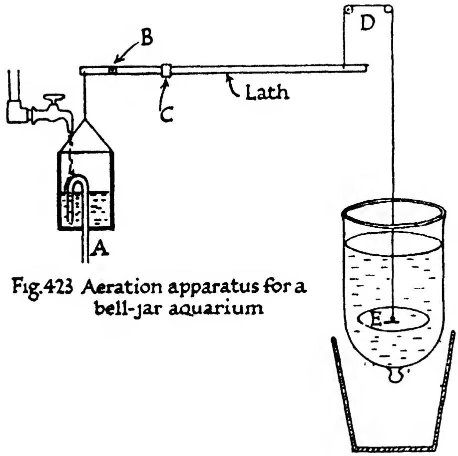


Fig. 423 Aeration apparatus for a bell-jar aquarium

D. Pulleys: By the use of pulley-wheels it is possible to arrange for the aeration of several bell-jars at a place far distant from the driving mechanism. Meccano pulley-wheels are very suitable, cotton reels can also be used.

E. Glass plate: This has a hole drilled through the centre. The cord passes through the hole and is secured to a short horizontal length of glass rod [199].

Mrs. Ayrton's sand-ripple apparatus. (Fig. 424.)

This demonstrates the formation of sand-ripples below the surface of moving water. Clean sand is placed at the bottom of a narrow, but comparatively deep tank of water. The tank is arranged on rollers and given a gentle side to side movement.

Well-formed sand ripples are quickly built up. The complex eddy movement of the water that produces the ripples, is made evident by the addition of a very small quantity of aluminium powder.

The back, two ends and the bottom of the tank are made from wood about 1″ thick. A suitable measurement for the inside space is 26″ × 18″ × 3″.

The wooden parts can be fastened together with 2¼″ iron screws. Plate glass must be used for the front. It is set in a groove measuring ¼″ wide and ⅝″ deep.

The joints are made water-tight with pitch. Start with the glass out of the groove. Obtain pitch from a ship's store or an oil and colour merchant and melt it in a saucepan, this is best done in a well ventilated situation. If the pitch catches fire cover the saucepan with a piece of tin plate.

Make the pitch completely fluid and paint it over the inside surface of the tank. Pour molten pitch into all the corners. Do each corner in turn and allow the pitch to set along one corner

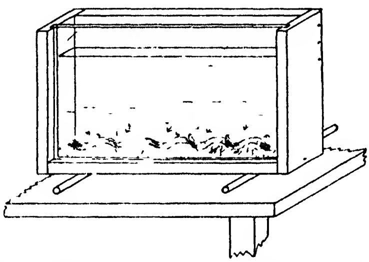


Fig. 424. Mrs. Ayrton's sand-ripple apparatus

before tilting the tank and treating a second one. Before cementing in the glass it is necessary to roughen the surface of the two polished faces along a band an inch wide as measured from the bottom and side edges of the glass. This is necessary to obtain a water-tight joint between the glass and the pitch.

Place the glass flat on a table and carry out the roughening by making scratches with a coarse carborundum stone or rub the glass with a cork frequently dipped into a mixture of water and carborundum or emery powder.

Slide the glass into the groove and fill the latter with pitch. The pitch, if thoroughly fluid, will flow under the edges of the glass and fill up the groove on both sides.

Keep the glass centralized in the groove during the pouring process.

The sand used must be well washed and free from all trace of mud. About one half a c.c. of aluminium powder is sufficient, avoid excess.

The construction of large aquaria. (Plate VIB.)

Large water-tight aquaria can be constructed by following the method given for a sand-ripple apparatus. The cost is little more than that of the plate-glass.

Second-hand plate-glass, old shop window-glass, can often be obtained from builders and glass merchants at a cheap rate. Motor-car wind-screens of the non-safety type can also be used.

The wooden parts can be screwed together or dove-tailed. If the inside of the aquaria be washed over after pitching with a mixture of water and cement a pleasing rock coloured background is obtained.

If the tanks be fitted with ¾″ iron overflow-pipes and arranged in step fashion, one slightly higher than the next, it is possible for water from a supply tap to flow from one to the other. The aquaria shown in Plate VIB have been in continuous use for four years. The roughening of the glass is essential. The pitch has no injurious effect on fish or water-plants, pike and trout have been kept for long periods in the aquaria illustrated.

It is advisable to arrange a box of perforated zinc over the exit to the overflow pipes since water snails tend to get into these pipes and block them up.

Very attractive illumination is obtained by placing electric lamps with deep cardboard shades over the aquaria.

A small tank. (Plate VIc.)

A small tank, with front and back made of plate glass, can be constructed as shown in Plate VIc. The bottom and sides are made of strips of wood, treated with shellac on the inside surfaces.

The glass can be set in grooves cut in the wood or held against the wooden framework with clamps made of strip steel, threaded rods ¼″ diam. and nuts. The glass should be roughened, as described for the sand-ripple apparatus (Fig. 424), and a very good water-tight joint can be made with one of the numerous plastic roof repairing compounds now on the market and stocked by all builders' merchants.

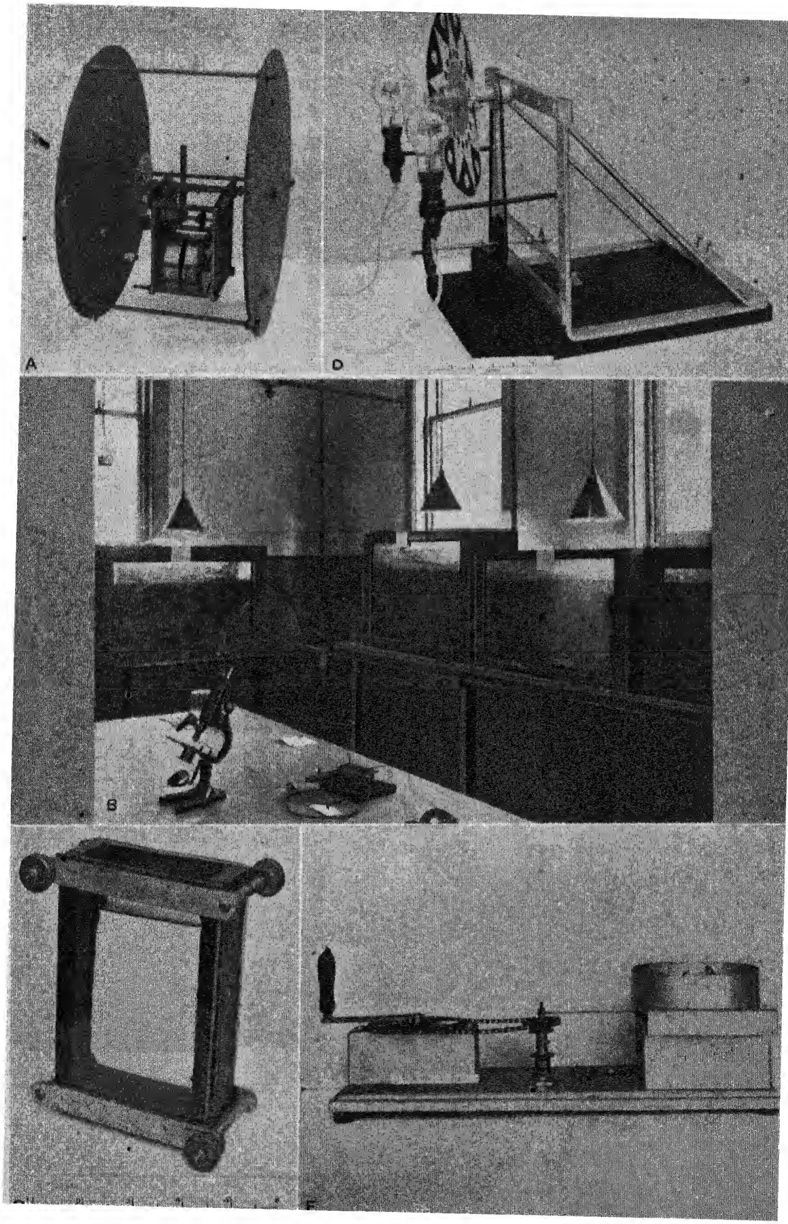
One such material is Rito manufactured by Andrew Maxwell, 6, St. Paul's Square, Liverpool.

The use of cycle hubs. (Plate VID.)

Cycle hubs provide excellent ball bearings in the construction of many forms of apparatus. A front hub, complete with spindle, can be bought for 2/3 and a rear one for 3/–. The spindles can be attached to a back plate of strip-steel and if necessary extended by the use of extension unions costing 2*d.* each or steps 3*d.* each. Extra hub nuts cost 1*d.* each.

Discs of metal or wood can be attached to the spoke flanges with small nuts and bolts, and spring curtain-rod makes a good

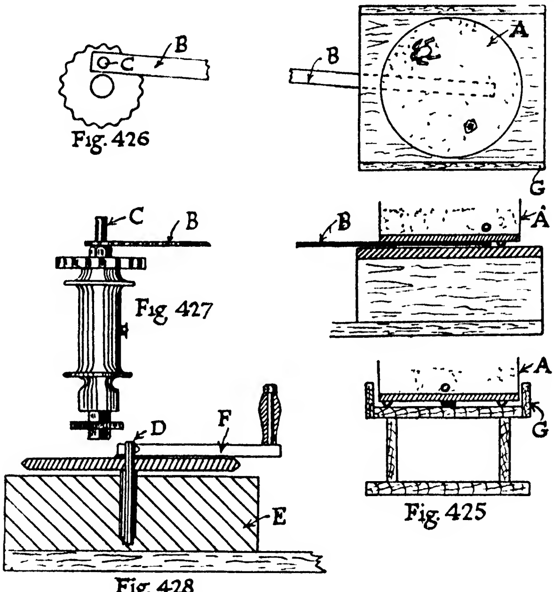
PLATE VI



A. Model to illustrate the mechanism of a motor-driven garden roller B. Aquaria
C. A small tank D. Whirling table with strobic disc E. A shaking sand box

driving band, as mentioned in connection with the neon lamp rotator, page 213.

Plate VID shows a whirling table made with a framework of strip steel and arranged for the study of a strobic disc illuminated by two Osglim neon lamps connected to an A.C. supply.



A shaking sand box

A shaking sand box. (Figs. 425–428 and Plate VIE.)

With this contrivance it is possible to show that sand acquires certain fluid properties when violently shaken.

Light objects such as celluloid frogs or ping-pong balls, previously buried in the sand, immediately rise to the surface and glass marbles or steel balls sink to the bottom.

Bicycle parts form part of the mechanism.

The sand box A, fig. 425, is 10″ in diam. and 3½″ deep. The base is a disc of wood and the side is a strip of sheet metal with a joint soldered to form a ring.

B is a length of strip brass or steel ½″ × ⅛″. It is firmly attached with screws to the bottom of the sand box. The projecting end has a ¼″ diam. hole drilled in it and fits over a pivot, a 2″ length of ¼″ diam. steel-rod C, threaded at the bottom and attached with nuts to the chain sprocket of a bicycle rear hub, figs. 426 and 427. The sprocket is quite easy to drill.

The hub-axle projecting on the sprocket wheel side is sawn off. The other end of the axle serves to secure the hub in a vertical position to a strip of 1″ × ¼″ steel bolted to the main baseboard.

The axle D of a driving sprocket wheel is driven, a tight fit, into a hole bored in a block of wood E, fig. 428.

The crank F is provided with a handle. The axle part of the handle can be made from a piece of ¼″ diam. steel-rod and the handle from a file handle. This has a full ¼″ diam. hole drilled through it and should be free to rotate on the axle.

The cotter pin of the pedal crank is not fitted.

The framework G that guides the sand box should be ½″ wider on the inside than the diameter of the box. This allows for side movement.

Four or five steel dome furniture-castors are driven into the under face of the sand box baseboard and serve to reduce friction.

Description of plates. (VII and VIII.)

The apparatus and models illustrated in Plates VII–VIII were made by African boys ages 14–18 at a college in Nigeria where classroom and workshop instruction go hand in hand.

Plates VIIA–C. Models of lifting machines.
Most of the constructional work was carried out in wood at very small cost. The derrick crane, Plate VIIA was fitted with a lifting electro-magnet.

Plate VIID. An automatic recording auxanometer for measuring the rate of growth of a cotton plant.

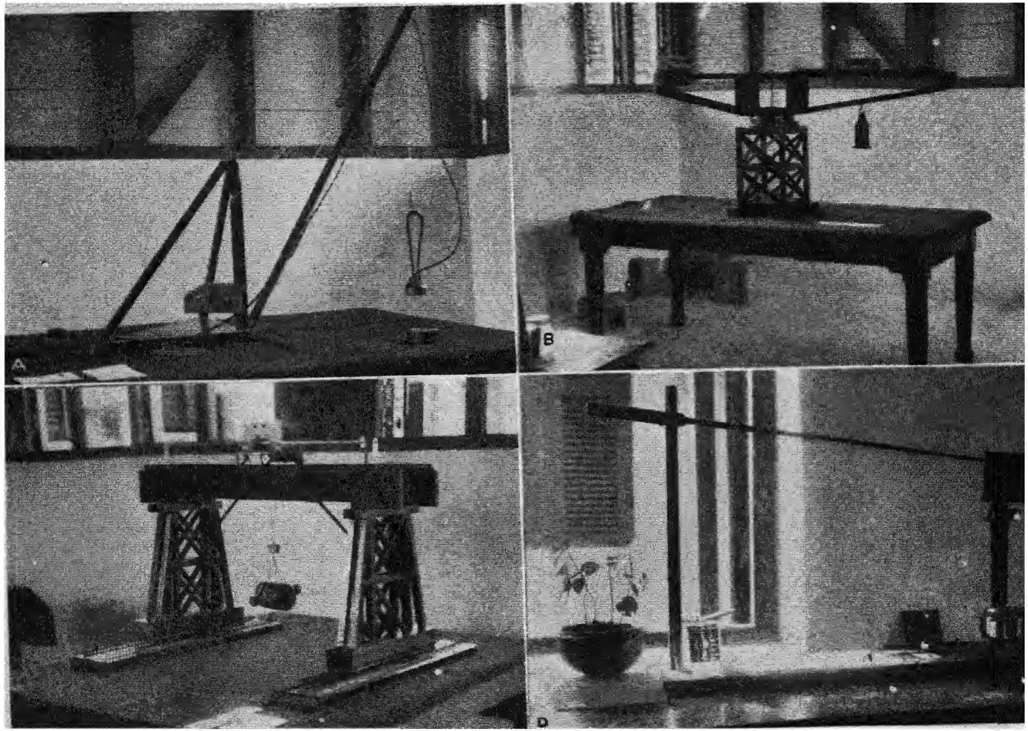
Plate VIIIA. Model of a mediæval system of farming used for the comparative study of methods of agriculture.

Plate VIIIB. Model of a castle. The walls were cut out of 3-ply wood and the moat, containing water, was made of sheet-zinc with soldered joints.

Plate VIIIC. Model of a lake village.

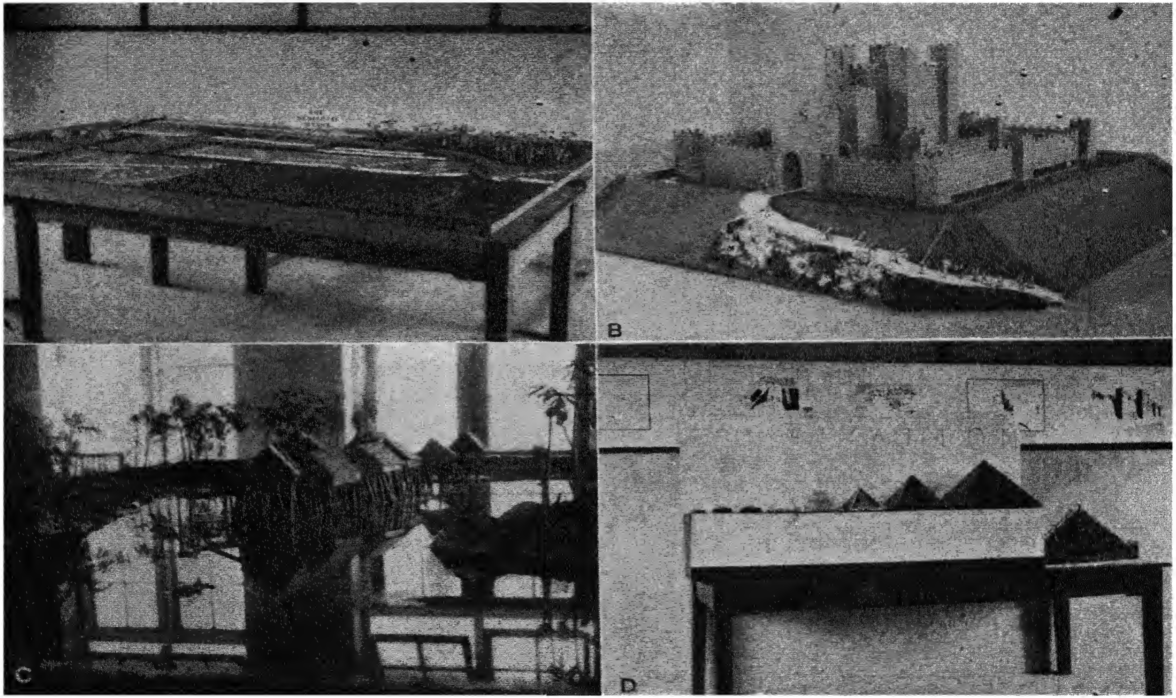
Plate VIIID. Historical models. Made of clay, cement-washed and painted.

PLATE VII



A. Derrick crane with lifting electro-magnet B. Hammer-headed crane
C. Travelling crane D. Automatic recording auxanometer

PLATE VIII



A. Model of a mediæval system of farming B. Model of a castle
C. Model of a lake village D. Historical models

APPENDIX

BOOKS AND PERIODICALS FOR A WORKSHOP LIBRARY

Carpentry.

WOODWORK TOOLS AND HOW TO USE THEM *by* William Fairham. (Evans Brothers.) 3 /6.

THE COMPLETE WOODWORKER, edited *by* Bernard E. Jones. (Cassell's Handcraft Library.) 8 /6.

THE COMPLETE AMATEUR WOODWORKER. (Handicrafts Ltd.) 6*d.*

STRIP WOODWORK AND MODEL MAKING. (Handicrafts Ltd.) 6*d.*

HANDICRAFTS ANNUAL. (Handicrafts Ltd.) 1 /–.

Drawing.

MECHANICAL DRAWING. (Cassell.) 3 /6.

HOW TO READ A WORKSHOP DRAWING *by* W. Longland. (Percival Marshall.) 9*d.*

Electric Wiring.

PRIVATE HOUSE ELECTRIC LIGHTING *by* Taylor. (P. Marshall.) 1 /6.

Meccano.

MECCANO INSTRUCTIONS. (Meccano Ltd.) 2 /6.

MECCANO STANDARD MECHANISMS. (Meccano Ltd.) 1 /–.

Metal Working.

THE PRACTICAL METAL WORKER. 3 Vols. (Cassell.) Obtainable from Waverley Book Co. 45 /–.

Workshop and Laboratory Arts.

WORKSHOP PRACTICE FOR THE SCHOOL AND LABORATORY *by* Barker and Chapman. (Sidgwick & Jackson.) 3 /6.

LABORATORY ARTS *by* G. A. Woollatt. (Longmans Green & Co.) 4 /6.

Photography.

THE BRITISH JOURNAL PHOTOGRAPHIC ALMANAC. Published annually. (Henry Greenwood.) 2 /–.

NATURE PHOTOGRAPHY *by* Pike. (Chapman & Hall.) 12 /6.

WELLINGTON PHOTOGRAPHIC HAND BOOK. (Wellington & Ward, Elstree.) 1 /–.

PHOTOGRAPHY MADE EASY *by* Child Bayley. (Iliffe.) 2 /6.

THE COMPLETE PHOTOGRAPHER *by* Child Bayley. (Methuen.) 15 /–.

Miscellaneous.

HOME MECHANICS. (Newnes.) 4 Vols. 63 /–.

THE AMATEUR MECHANIC. 4 Vols. (Waverley Book Co.) 62 /6.

THINGS WORTH MAKING *by* Archibald Williams. (Nelson.) 5/–.
THINGS TO MAKE *by* Archibald Williams. (Nelson.) 5/–.
SCIENCE MASTERS' BOOK. Part I: Physics; Part II: Chemistry and Biology, (Murray.) 7/6 each.
MODELS OF BUILDINGS *by* William Harvey. (The Architectural Press, London.) 7/6.
SCENIC MODELLING *by* Edward W. Hobbs. (Cassell.) 1/6.
TOY MAKING FOR AMATEURS. (Newnes' *Home Mechanic* Series.) 1/–.
THE HANDYMAN'S ENQUIRE WITHIN. (Newnes' *Home Mechanic* Series.) 1/–
25 SIMPLE WORKING MODELS. (Newnes' *Home Mechanic* Series.) 1/–.
SIMPLE ELECTRICAL APPARATUS. (Newnes' *Home Mechanic* Series.) 1/–
HARPER'S ELECTRICITY BOOK FOR BOYS. (Harper.) 7/6.
The *Model Engineer* Series, Percival Marshall. 9*d.* each.
SOLDERING, BRAZING, AND THE JOINING OF METALS.
ELECTRIC BELLS AND ALARMS.
TELEPHONES AND MICROPHONES.
SIMPLE ELECTRICAL WORKING MODELS.
SIMPLE MECHANICAL WORKING MODELS.
INDUCTION COILS FOR AMATEURS.
SIMPLE SCIENTIFIC EXPERIMENTS.
SMALL ELECTRICAL MEASURING INSTRUMENTS.
THE WIMSHURST MACHINE.
HARDENING AND TEMPERING ENGINEERS' TOOLS.
CLOCK REPAIRING AND ADJUSTING.
WATCH REPAIRING AND ADJUSTING.
ELECTRICAL APPARATUS MAKING *by* Ballhatchet. (Percival Marshall.) 3/–.
MORE ELECTRICAL APPARATUS MAKING *by* Ballhatchet. (Percival Marshall.) 3/–.

PERIODICALS

Weekly.

English Mechanics, 3*d*. *Hobbies*, 2*d*. *Model Engineer*, 4*d*. *Amateur Photographer*, 3*d*.

Monthly.

The Woodworker Magazine, 6*d*. *Handicrafts Monthly Magazine*, 3*d*. *Meccano Magazine*, 6*d*.

The following are published in America:

Monthly.

Popular Mechanics, 2/–. *Modern Mechanics*, 1/6. *Science and Invention*, 2/–. *Popular Science*, 1/3. *Scientific American*, 2/–.

The Journal of the Science Masters' Association. (*Murray.*) 2/6 *Quarterly.*

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